The Role of Cognitive Biases and Executive Functions in Adolescent Worry

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Abstract

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Worry is common in childhood and adolescence. In moderation, worry can serve as an adaptive response in anticipation to perceived threat. However, some young people experience excessive, uncontrollable, and persistent worries that cause significant distress and impairments to daily functioning. Research presented in this thesis investigated the role of cognitive biases and executive functions in adolescent worry. In Chapter Two, a systematic review examined the existing literature on child and adolescent worry and found that cognitive biases and executive functions were associated with worry in youth. The systematic review identified some of the gaps in the child and adolescent literature on worry, which provided a research framework for subsequent studies in this thesis. Chapters Three and Four presented data from the CogBias Longitudinal study and showed that interpretation and memory biases were closely interrelated cognitive processes associated with adolescent worry. Furthermore, Chapter Four found that negative biases played a causal role in the manifestation of worry from early to mid-adolescence. Chapters Five and Six, investigated the role of executive functions in adolescent worry. Findings in Chapter Five, indicated that attentional control and working memory were not associated with worry in adolescence. Moreover, these executive functions did not moderate the association between cognitive biases and worry. In Chapter Six, an experimental study was designed to assess the effect of active worry on working memory capacity using a worry induction paradigm in a community sample of adolescents. In line with the findings of Chapter Five, active worry did not impair working memory capacity in adolescents. The research presented in this thesis indicates that cognitive biases are mechanisms underlying worry in adolescence, however evidence that executive functions play a role in adolescent worry was not supported. Future research using longitudinal and experimental designs would provide further insight into the causal mechanisms underlying worry in adolescence and how these cognitive processes interact and develop over time.

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Declaration

This thesis comprises work conducted by Annabel Songco for the degree of Doctor of Philosophy from the University of Oxford. Annabel Songco contributed significantly to the design, recruitment, and data collection of the research presented in each chapter of this thesis. Annabel Songco has led all of the work included in this thesis. Several chapters (Chapters Three, Four, and Five) were conducted as part of the CogBias Longitudinal study, a three-wave longitudinal study in adolescence. Annabel Songco was the Research Assistant and project lead for the CogBias Longitudinal study and assisted with recruitment, data collection, study design, ethical consent, and data management for the duration of the three-waves of the project, in collaboration with other members of the research lab. Chapters Three, Four, and Five presents a subset of the completed data-set of the CogBias Longitudinal study and the conception of novel research questions and data analysis of these chapters was led by Annabel Songco. The study design of Chapter Six was developed by Annabel Songco and recruitment and data collection was conducted in secondary schools independent of the CogBias Longitudinal study.

"It is easier to build strong children than to repair broken men."

- Frederick Douglass, 1855

Contents

Chapter 1

1

Introduction

1.1. When worry becomes a cause for concern

Worry is common in children and adolescents. For many young people, worry is temporary and an adaptive process that may help them think about how to deal with challenging future events. However, some young people experience excessive and uncontrollable worries that persist over time and significantly impair daily functioning. In contrast to normal worry, pathological worry is chronic and disabling, where minor day-to-day issues become overwhelming and lead to increased distress. This pathological worry is a central feature of generalized anxiety disorder (GAD) and is a characteristic of several other anxiety disorders including social anxiety disorder (SAD), obsessive-compulsive disorder (OCD), and post-traumatic stress disorder (PTSD) (American Psychiatric Association, 2013). The research presented in this thesis was conducted to provide a deeper understanding of the cognitive components of worry in adolescence.

1.2. The nature of worry in youth

Worry has been described as the cognitive component of anxiety (Borkovec, Shadiek, & Hopkins, 1991) and involves repetitive thoughts and images that focus on the potentially negative outcomes of future events (Vasey & Daleiden, 1994). Evidence in the youth literature shows that the capacity to worry in a generalised way emerges from the age of eight, which increases in complexity with age due to the development of cognitive skills that enable individuals to anticipate future events and their consequences (Vasey, 1993). This suggests that cognitive mechanisms play an important role in the development and nature of worry throughout childhood and adolescence, which may serve as important cognitive pathways to the aetiology of anxiety disorders. Throughout this thesis, worry is conceptualised as one of the cognitive components of anxiety, and as an endophenotype and precursor to the manifestation of anxiety disorders, in particular to GAD.

1.3. The importance of worry in adolescents

Adolescence is broadly defined as a period that begins at the onset of puberty and ends when an individual attains independence (Damon, 2004). Recent neuroimaging studies show that adolescence represents a sensitive period, following early childhood, that is characterised by significant changes in brain structure and function (Steinberg, 2014). This heightened neuroplasticity in brain development has been linked to improvements and changes in cognitive functions including working memory, problem-solving, intelligence, and social cognition (Fuhrmann, Knoll, & Blakemore, 2015). Adolescence is a key developmental stage associated with worry (Copeland, Angold, Shanahan, & Costello, 2014) and thus the experience of worry during this period may have a heightened impact on adult functioning. Therefore, adolescence may offer a unique opportunity to turn the development of pathological worry around in its early stages. Appropriate interventions that target the key underlying mechanisms of worry are likely to be particularly effective during this period of development. The studies presented in this thesis aim to identify the cognitive mechanisms that underpin the process of worry in adolescence, which can be used to improve current treatments and early interventions.

1.4. A cognitive theoretical framework

In the adult literature, several theoretical models emphasise the critical role of cognitive processes in the development and maintenance of worry (Behar, DiMarco, Hekler, Mohlman, & Staples, 2009). In contrast, the cognitive processes underlying worry in adolescence are poorly understood. Whilst evidence suggests that some aspects of worry in adults are similar to those in adolescents, it is not clear to what extent adult models of worry and GAD are fully applicable to younger populations. The research presented in this thesis focuses on Hirsch and Matthews' cognitive model of pathological worry (2012), which provides a strong evidence-based framework that integrates the importance of negative cognitive biases and deficits in executive functions in the aetiology of adult worry. Cognitive biases, also referred to as information-processing biases in this thesis, and executive functions have shown to play a crucial role in the development and maintenance of pathological worry in adults. However, there has been limited research examining how these cognitive processes operate during adolescent worry, which may provide valuable insights into the risk mechanisms underlying worry in youth. The body of work presented in this thesis draws on Hirsch and Matthews' cognitive model of pathological worry (2012) as a theoretical framework for understanding the cognitive processes that contribute to adolescent worry and examining how these basic processes operate in the early stages of worry in adolescence, which may help guide future research.

1.5. Key research questions

The primary aim of this thesis was to investigate the role of cognitive biases and executive functions in adolescent worry. In particular, the research described in this thesis uses Hirsch and Matthews' cognitive model of pathological worry (2012) as a theoretical framework to systematically address whether cognitive biases and executive functions, which are widely explored in the adult literature of worry, operate in similar ways in adolescent worry. A deeper understanding of the cognitive mechanisms underlying adolescent worry may help to identify the processes to target and improve interventions for worry in youth. The theoretical and empirical chapters presented in this thesis use correlational, experimental, and longitudinal designs to extend the current literature on adolescent worry and address three key questions:

Research Question 1: Are cognitive biases associated with worry in adolescents, and what is the causal nature of these cognitive processes over time?

Research Question 2: Are executive functions associated with worry in adolescents, and how does high worry impact executive functions?

Research Question 3: Do executive functions moderate the relationship between cognitive biases and worry as proposed in Hirsch and Matthews' cognitive model of pathological worry (2012), and is this model applicable to understanding adolescent worry?

These research questions will be addressed in the following chapters:

Chapter Two systematically reviews the existing literature on child and adolescent worry and examines the cognitive biases and executive functions associated with worry in youth. In particular, the systematic review evaluates the application of Hirsch and Matthews' cognitive model of pathological worry (2012) in understanding child and adolescent worry. The results of the systematic review identifies some of the gaps in the literature on child and adolescent worry, which help guide the research in this thesis to further investigate the cognitive components of worry in adolescence.

Chapter Three investigates the association between cognitive biases and worry in adolescents. Specifically, this chapter examines whether attention bias, interpretation bias, and memory bias are related to levels of worry in adolescents. Furthermore, in line with the combined cognitive bias hypothesis, Chapter Three assesses whether attention, interpretation, and memory biases are interrelated cognitive processes that influence each other in adolescent worry. Data is drawn from time point 1 of the CogBias Longitudinal study, which investigates the cognitive and genetic mechanisms underlying emotional vulnerability and resilience in adolescents.

Chapter Four is a study designed to build on the findings of Chapter Three and examines the causal relationship between cognitive biases and worry in adolescents over time. In particular, this chapter investigates whether cognitive biases or worry causally precedes the other using structural equation modelling with a cross-lagged panel model. The chapter presents data drawn from time point 1 and follow up data from time point 2 of the CogBias Longitudinal study, to assess how these cognitive processes develop over time from early to mid-adolescence.

Chapter Five addresses the second and third research questions of whether executive functions play a role in adolescent worry. The chapter examines whether attentional control and working memory are associated with worry in adolescents, using data from time point 2 of the CogBias Longitudinal study. Furthermore, to test the applicability of Hirsch and Matthews' model of pathological worry in adolescents, we investigate whether attentional control or working memory moderates the relationship between cognitive biases and worry in adolescents.

Chapter Six is an extension of Chapter Five and further explores the association between executive functions and worry in adolescents. The chapter addresses one of the limitations of correlational research by using an experimental paradigm to investigate the direct effect of active worry on working memory. Specifically, the study uses a worry induction paradigm that has been validated in adolescent and adult populations to assess the impact of high worry on verbal and visuospatial working memory capacity.

Chapter Seven summarises the main findings presented in the theoretical and empirical chapters of the thesis and discusses the research in light of considerations and future directions for adolescent worry.

Chapter 2

2

Pathological Worry in Children and Adolescents: A Systematic Review

Worry is common in children and adolescents, yet some young people experience excessive worries that cause significant distress and interference in their daily lives. This pathological worry is a risk factor for a range of negative outcomes and is a defining feature of generalized anxiety disorder (GAD). Whilst the literature on worry and GAD in adults is well established, the cognitive mechanisms underlying child and adolescent worry are less well understood. The cognitive model of pathological worry proposed by Hirsch and Matthews (2012) explains the causal role of information-processing biases, executive functions, and verbal worry in the aetiology of pathological worry in adults. This systematic review investigated whether there is evidence for this cognitive model of pathological worry in children and adolescents. Implications of these findings and future directions are discussed. We then present a cognitive model of child and adolescent worry, which provided a framework to guide the research presented in this thesis.

2.1. Introduction

2.1.1. Child and adolescent worry

Worry is a cognitive process involving intrusive thoughts and images that focus on the potentially negative outcomes of future events (Vasey & Daleiden, 1994). Described as a response to the anticipation of threat and the avoidance of perceived danger, worry is an attempt to engage in mental problem solving when faced with uncertainty (Mathews, 1990). Research shows that worry is common in children and adolescents and varies continuously across the normal population (Goncalves & Byrne, 2013). In moderation, worry can serve as an adaptive process that enables problem solving, prepares individuals for future threat, and can increase motivation and concentration (Davey, 1994; Watkins, 2008). However, on the other end of the spectrum, pathological worry is of clinical concern and is characterised by excessive and uncontrollable worries that cause significant distress.

Pathological worry in children and adolescents is associated with poor academic functioning, school absenteeism, severe difficulty concentrating, withdrawal from social activities, irritability, and disrupted sleep patterns (Albano & Hack, 2004). Studies show that children and adolescents worry about a range of issues relating to school, relationships, health, as well as interpersonal and social issues (Muris, Meesters, Merckelbach, Sermon, & Zwakhalen, 1998; Silverman, La Greca, & Wasserstein, 1995). Furthermore, research on gender differences indicate that females show higher levels and frequencies of worry compared with males (Barahmand, 2008; Caes, Fisher, Clinch, Tobias, & Eccleston, 2016; Muris, Meesters, & Gobel, 2001). When left untreated, high worry is a risk factor for the development of anxiety disorders, with many adults reporting that their excessive worries began to develop in childhood or adolescence (Costello, Egger, & Angold, 2005; Pine, Cohen, Gurley, Brook, & Ma, 1998). Excessive worry is one of the core features of generalized anxiety disorder (GAD) (American Psychiatric Association, 2013) and lifetime prevalence of GAD among youth range from 2% to 6% (Kessler et al., 2005; Merikangas et al., 2010), with early onset occurring from middle childhood onwards (Yonkers, Bruce, Dyck, & Keller, 2003). Thus, pathological worry is a debilitating mental health problem in children and adolescents with long-term negative consequences.

Childhood and adolescence entails major cognitive, social, and physiological changes that can have an impact on the development of worry (Copeland, Angold, Shanahan, & Costello, 2014). Recent studies in adolescents show heightened sensitivity and neuroplasticity in brain development, where certain cognitive skills, thought patterns, and behaviours are particularly malleable (Fuhrmann et al., 2015; Steinberg, 2014). Perhaps this heightened sensitivity during adolescence may explain why pathological worry often emerges during this period, as certain maladaptive thoughts and behaviours become more habitual. Furthermore, neuroimaging studies in adolescents reveal distinct structural and functional changes in the pre-frontal cortex that have been shown to improve working memory (Tamnes et al., 2013), problem solving (Squeglia, Jacobus, Sorg, Jernigan, & Tapert, 2013), and social cognition (Cohen Kadosh, Johnson, Henson, Dick, & Blakemore, 2013). Therefore, late childhood and adolescence may represent a vulnerable period that offers a unique opportunity to turn the development of worry around in its early stages. However, despite the early onset and the negative consequences associated with high worry in children and adolescents, research examining the cognitive mechanisms underlying the development and maintenance of worry in youth remains scarce.

2.1.2. Cognitive factors associated with worry

The critical role of cognitive factors in the aetiology of worry in adults is well-established. A wealth of empirical evidence shows that pathological worry in adults arises due to cognitive factors such as; the avoidance of processing threats in the form of imagery due to their greater emotional impact (Borkovec, 1994), maladaptive beliefs about the benefits and detriments of worry (Wells, 1995), intolerance of uncertainty (Dugas, Gagnon, Ladouceur, & Freeston, 1998), negative cognitive biases in combination with deficits in attentional control (Eysenck, Derakshan, Santos, & Calvo, 2007; Hirsch & Mathews, 2012), lack of problem solving confidence (Davey, 1994), an inability to regulate emotions (Mennin, Heimberg, Turk, & Fresco, 2005), and high levels of emotional reactivity (Newman & Llera, 2011). Theoretical models based on these findings have contributed to a deeper understanding of worry in adults, facilitating the development of treatments for GAD (Behar et al., 2009). Overall, cognitive models remain the dominant approach for explaining the underlying processes that cause and maintain worry and anxiety in adults.

In contrast, there is less known about the defining characteristics of worry and GAD in children and adolescents, with few cognitive developmental models of worry (Kertz & Woodruff- Borden, 2011; Vasey, 1993). The absence of a developmentally appropriate understanding of worry, often results in adult conceptualisations of worry being applied to children and adolescents (Cartwright-Hatton, Reynolds, & Wilson, 2011). Evidence suggests that some cognitive elements of adult models of GAD are applicable to child and adolescent worry. Intolerance of uncertainty, for instance, is an important cognitive risk factor in the manifestation of worry in youth. It is a central feature of the Intolerance of Uncertainty model of GAD (Dugas et al., 1998) and defined as the negative way an individual perceives, interprets, and responds to novel situations. Studies have shown that children and adolescents with high worry and GAD demonstrate greater levels of intolerance of uncertainty compared to non-anxious youth (Donovan, Holmes, & Farrell, 2016; Dugas, Laugesen, & Bukowski, 2012; Fialko, Bolton, & Perrin, 2012; Kertz & Woodruff-Borden, 2013; Thielsch, Andor, & Ehring, 2015).

In addition, metacognitive beliefs, as outlined in Well's Metacognitive Model of GAD (1995), have been extensively examined in child and adolescent worry (Bacow et al., 2010; Donovan et al., 2016; Ellis & Hudson., 2010; Esbjorn et al., 2015; Fialko, Bolton, & Perrin, 2012; Smith & Hudson, 2013; Thielsch et al., 2015; White & Hudson, 2016). Studies indicate that negative beliefs about the harmful nature of worry is a contributing factor to worry in youth. However, contrary to the adult literature, there have been mixed findings that endorsing positive beliefs about the usefulness of worry is associated with child and adolescent worry. Broadly, these findings suggest that cognitive processes similar to those in adults may also influence child and adolescent worry. Although, it is not clear to what extent adult cognitive models of GAD are fully applicable to younger populations, given the developmental changes experienced throughout childhood and adolescence.

2.1.3. Developmental models of worry

Few developmental models highlight the cognitive pathways that lead to pathological worry in children and adolescents (Kertz & Woodruff-Borden, 2011; Vasey, 1993). Vasey's influential model of worry (1993) proposes that certain cognitive abilities such as the capacity to anticipate future events and elaborate on threatening possibilities, are necessary to engage in the process of worry. Vasey argues that the capacity, complexity, and elaboration of worry increases from middle childhood, at the age of eight onwards, as children develop cognitive skills that enable them to consider future outcomes through deductive reasoning (Vasey, Crnic, & Carter, 1994). During adolescence, worry becomes more prominent with the development of abstract thinking and the cognitive ability to foresee multiple negative outcomes (Vasey & Daleiden, 1994). Empirical evidence supports Vasey's model of worry and the role of cognitive maturation in children's experience of worry (Muris, Merckelbach, Gadet, & Moulaert, 2000; Muris, Merckelbach, Meesters, & van den Brand, 2002). However, research on the cognitive developmental factors that influence worry and how the nature of worry changes across childhood and adolescence is limited.

Another key developmental model of worry (Kertz & Woodruff-Borden, 2011) captures the complex interplay between genetics, temperament, cognition, emotion, and parental risk factors. Kertz and Woodruff-Borden (2011) propose that temperament and genetics play an important role in a child's predisposition towards worry or anxiety. These biological vulnerability factors together with parental factors, such as parental anxiety and parenting behaviours, are hypothesised to relate to cognitive risk factors such as information-processing biases, intolerance of uncertainty, and metacognitive beliefs about worry. The theoretical model highlights several risk factors and potential pathways in the aetiology of worry in youth, with evidence supporting several aspects of the model pertaining to the role of genetics, child temperament, parental factors, and environmental influences in the transmission of pathological worry (Aktar, Nikolic, & Bögels, 2017; Hudson & Rapee, 2004). However, there is limited empirical research supporting the cognitive pathways to GAD, in particular, the role of information-processing biases in worry.

Research on information-processing biases, also referred to as cognitive biases, in children and adolescents has predominately focused on anxiety and mood disorders, and not specifically, on how information is processed during worry (Dudeney, Sharpte, & Hunt, 2015; Haller, Cohen Kadosh, Scerif, & Lau, 2015; Muris, 2010; Lau & Waters, 2016; Pine & Fox, 2015; Platt, Waters, Schulte-Koerne, Engelmann, & Salemink, 2016). Cognitive models of anxiety in youth propose that anxiety manifests through the selective-processing of threat related stimuli during the encoding, interpretation, and response stages of information-processing (Crick & Dodge, 1994; Daleiden & Vasey, 1997; Field, Hadwin, & Lester, 2011; Kendall, 1985; Muris & Field, 2008; Murray, Creswell, & Cooper, 2009; Vasey & Daleiden, 1994).

Studies have shown that anxious youth exhibit selective attention towards threat in comparison to non-anxious youth (Dudeney et al., 2015; Puliafico & Kendall, 2006). In addition, anxious youth demonstrate more threat interpretations of ambiguous information relative to non-anxious youth (Castillo & Leandro, 2010; Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2017). Whilst a growing body of evidence indicates that impairments in executive functions such as attentional control and working memory are also associated with greater levels of anxiety in youth (Kertz, Belden, Tillman, & Luby, 2016; Vilgis, Silk, & Vance, 2015). However, the role of cognitive biases and executive functions in child and adolescent worry remains a relatively neglected area of empirical enquiry, which may be an important endophenotype in the cognitive pathways to anxiety disorders.

2.1.4. The cognitive model of pathological worry

Hirsch and Matthews' cognitive model of pathological worry (2012) integrates the importance of negative cognitive biases and deficits in attentional control in the aetiology of adult worry. The model proposes three fundamental building blocks that cause and maintain pathological worry. These are: information-processing biases that selectively prioritise threatening stimuli, difficulties with the executive control of attention, and the quasi-verbal form of worry. Hirsch and Matthews' (2012) suggest that a combination of these three component processes results in a potent form of pathological worry, as seen in GAD, that is, generalised, excessive and uncontrollable. In addition to these three main component processes, the model draws on theoretical aspects from prior cognitive models of GAD to illustrate that pathological worry may be maintained through intolerance of uncertainty (Dugas et al., 1998), emotion dysregulation (Mennin et al., 2005), and maladaptive beliefs (Wells, 1995). The applicability of Hirsch and Matthews' cognitive model to understanding child and adolescent worry is yet to be examined and could provide valuable insights into the cognitive risk mechanisms underlying worry in youth.

There is strong empirical evidence supporting key aspects of Hirsch and Matthews' (2012) cognitive model of pathological worry. Firstly, cognitive biases have been shown to play an important role in the aetiology of adult worry and GAD (Cisler & Koster, 2010; Mathews & MacLeod, 2005). According to information-processing models, negative cognitive biases are mechanisms that cause and maintain psychopathology (Beck, Emery, & Greenberg, 1985; Beck, Rush, Shaw, & Emery, 1979; Williams, Watts, MacLeod, & Mathews, 1997). Adults with high levels of worry or GAD demonstrate selective attention towards threat (Bradley, Mogg, White, Groom, & de Bono, 1999; Hayes, Hirsch, & Mathews, 2010; MacLeod, Mathews, & Tata, 1986) and are slower to disengage away from threat (Fox, Russo, Bowles, & Dutton, 2001). Moreover, they have a tendency to interpret ambiguous scenarios as threatening (Hirsch, Hayes, & Mathews, 2009; Matthews & MacLeod, 2005). Hirsch and Matthews' (2012) propose that negative cognitive biases are relatively involuntary 'bottom-up' processes responsible for negative thoughts initially intruding into awareness.

The second building block outlined in Hirsch and Mathews' model of worry (2012) relates to deficits in the central executive function of working memory or attentional control. Attentional control encompasses executive functions that refer to the ability to effectively ignore distracting information or shift attention from one topic to another (Miyake et al, 2000). Whilst working memory involves the ability to store information in mind and mentally manipulate it to perform certain tasks vital for reasoning, decision making, and planning (Baddeley & Hitch, 1994). In contrast to cognitive biases, executive functions involve voluntary 'top-down' processes associated with higher cortical structures. Experimental studies in adults have provided evidence that worry and GAD are associated with poor attentional control and reduced working memory capacity (Eysenck et al., 2007; Fox, Dutton, Yates, Georgiou, & Mouchlianitis, 2015; Hayes et al., 2008; Leigh & Hirsch, 2011; Moran, 2016). The cognitive model of pathological worry (2012) asserts that worry is responsible for taking up attentional control resources and working memory capacity available for other tasks, thus impairing the ability to redirect worrisome thoughts.

The cognitive model proposes that pathological worry arises from an interaction between 'bottom-up' involuntary processes, such as attention and interpretation biases towards threatening information, and 'top-down' voluntary processes in the executive control of attention. In individuals not prone to worry, the assumption is that when a threatening thought intrudes into awareness, effortful control processes operate efficiently to inhibit the representation of threat. In low worriers, a stronger activation of attentional control processes successfully prevents negative intrusions from entering into awareness. In marked contrast, for those individuals prone to high worry, negative intrusions are more likely to enter into awareness due to the stronger influence of pre-existing cognitive biases and habitual thought patterns. Once the threat representation intrudes into awareness, a depleted executive control of attention is insufficient to overcome the negative intrusion. Consequently, a worry episode develops in the form of verbal thoughts that are excessive and uncontrollable.

The predominantly verbal nature of worry represents the third component process of Hirsch and Matthews' cognitive model of pathological worry (2012). The model proposes that pathological worry is characterised by verbal thoughts that are relatively non-specific and general. The authors suggest that this verbal-linguistic form of worry is more potent than imagery based worry as it gives rise to abstract negative outcomes that are typically vague and difficult to resolve. Studies in adults have found that verbal worry functions as a form of cognitive avoidance of the negative outcomes evoked by mental imagery (Borkovec & Inz, 1990). Moreover, evidence shows that a consequence of verbal worry is that it increases subsequent negative intrusions compared to imagery of worry content (Butler, Wells, & Dewick, 1995; Leigh & Hirsch, 2011; Stokes & Hirsch, 2010).

Hirsch and Matthews' argue that worry is maintained through maladaptive cognitive biases and habitual thought patterns that become automatic over time. In addition, interpretation and attention biases continue to operate on the content of negative intrusions even after the verbal thought enters into awareness, which further escalates the worry episode. This cycle of negative intrusions, makes it difficult for subsequent attentional control processes to redirect thoughts away from worry onto neutral topics. Furthermore, the model suggests that cognitive factors such as inappropriate beliefs about the usefulness or dangers of worry (Wells, 1995), intolerance of uncertainty (Dugas et al., 1998), and the inability to regulate emotions (Mennin et al., 2006) also serve to maintain pathological worry. Hirsch and Matthews' (2012) cognitive model of pathological worry provides a strong evidence-based framework that integrates the importance of cognitive biases, executive functions, and the verbal processing of worry in the development and maintenance of pathological worry.

Whilst a large body of empirical work supports the cognitive model of pathological model (2012) in adults, relatively few studies have examined how these cognitive processes might operate and contribute to worry in children and adolescents. This is a clear gap in the literature and to date, no systematic review has investigated the role of cognitive biases and executive functions in worry or GAD in children and adolescents. Therefore, the objective of the current review was to examine existing evidence for the cognitive model of pathological worry in children and adolescents, and evaluate the applicability of the model in understanding worry in youth. In relation to the first fundamental building block, the current review investigated existing evidence for the association between worry and attention, interpretation, and memory biases in children and adolescents. These cognitive biases, featured in information-processing models of anxiety in youth, are hypothesised to play a role in the maintenance and exacerbation of childhood anxiety (Kendall, 1985; Crick & Dodge, 1994; Muris & Field, 2008).

In addition, the review examined existing evidence in youth of an association between worry and attentional control, working memory, and the verbal processing of worry as outlined in the second and third fundamental building blocks of Hirsch and Matthews' cognitive model. Furthermore, evidence for an association between emotion regulation and worry in youth was also examined in the current review. In recent years, there has been growing interest in understanding how emotion regulation develops over the developmental period of adolescence and how this 'top-down' executive control process relates to pathological worry (McRae et al., 2012; Sebastian et al, 2011; Silvers et al., 2012). Given that intolerance of uncertainty and metacognitive beliefs have been widely examined in the child and adolescent literature, the current study focused on reviewing evidence for emotion regulation as one of the maintaining factors proposed in Hirsch and Matthews' model.

Clinical and non-clinical studies that investigated the association of cognitive biases, executive functions, and the verbal nature of worry in child and adolescent worry or GAD were reviewed. We then proposed a theoretical model of child and adolescent worry to help guide future research on the cognitive mechanisms underlying worry in children and adolescents. A deeper understanding of how these cognitive mechanisms operate in child and adolescent worry would provide a greater insight into the psychological processes to target in treatments and early interventions.

2.2. Method

A systematic review of the literature was conducted in February 2018 following the PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). Studies were identified by searching electronic databases, scanning references and citations of articles, and consultation with experts in the field. The search was applied to the PsycINFO (1987 – 28th February 2018), MEDLINE (1974 – 28th February 2018), EMBASE (1946 – 28th February 2018), and PubMed electronic databases. A range of subject headings and search terms were used to obtain articles relevant to the three building blocks in the cognitive model of pathological worry (Hirsch & Matthews, 2012) in relation to children and adolescents (see Appendix A). Therefore, the search comprised of key terms related to: *Information-processing biases* ("cog* bias" or "cog* process*" or "cog* process* bias*" or "cog* factor*" or "information process* bias" or "emotion process* bias" or "cog* model" or "attention* bias" or "interpret* bias" or "memory bias"); *Executive functions* ("atten* control" or "executive function*" or "cog* control" or "inhibit* control" or "executive control" or "emotion* control" or "emotion*regulation" or "working memory" or "cog* flexibility" or "inhibition" or "set shifting" or "updating"); and *Verbal processing of worry* ("verbal" or "intrusive thought*" or "neg* intrusion*"). These search terms were all paired with terms related to *Worry* ("worry" or "generalized anxiety disorder" or "GAD") and the terms "child*" or "adolescen*" or "youth".

In the initial search of the four databases, 1527 articles were retrieved. After duplicates were removed, the titles and abstracts of 919 articles were screened for relevance and 57 full-text articles were retrieved for further screening. The full-text articles were screened and resulted in 27 studies from the database eligible for inclusion in the current review. Three additional articles were identified by searching through relevant journals, which resulted in 30 studies included in the systematic review (see Figure 2.1) In addition, the two authors performed a quality assessment of each study included in the systematic review by recording a checklist of ratings using an established quality assessment tool (Effective Public Health Practice Project, 1998). This was conducted to assess the risk of bias and discrepancies between the two authors were resolved through discussion (See Appendix A, Table A.1 for quality checklist).

Studies were eligible for inclusion in the current systematic review if they examined information-processing biases, executive functions, and the verbal nature of intrusive thoughts in relation to worry or GAD in children and adolescents. The inclusion criteria included; children and adolescents up to the age of 18; clinical and non-clinical studies that used a standardised measure of worry or GAD; clinical studies that included participants with a diagnosis of GAD; and studies that reported outcomes specific to GAD in comparison to non-anxious or non-GAD groups. This decision was made in order to address the specificity of worry relevant to Hirsch and Matthews' cognitive model, that is, pathological worry in GAD, as opposed to overall anxiety. The upper age limit of 18 years old was selected to provide a broad age range to include adolescents attending secondary school education. This upper age limit constitutes the typical age of adolescents in their final years of secondary school education in the UK and reviewing studies within this age range provides an understanding of worry that coincides with the subsequent samples included in this thesis. Further criteria included original articles published in peer-reviewed journals and studies available in the English language. Review papers and opinion pieces were excluded from the systematic review. We also excluded studies that investigated cognitive bias modification (CBM) in child and adolescent anxiety, in light of recent reviews that assessed the efficacy of CBM in anxious youth (Lau, 2013; Lau, 2015; Krebs et al., 2018).

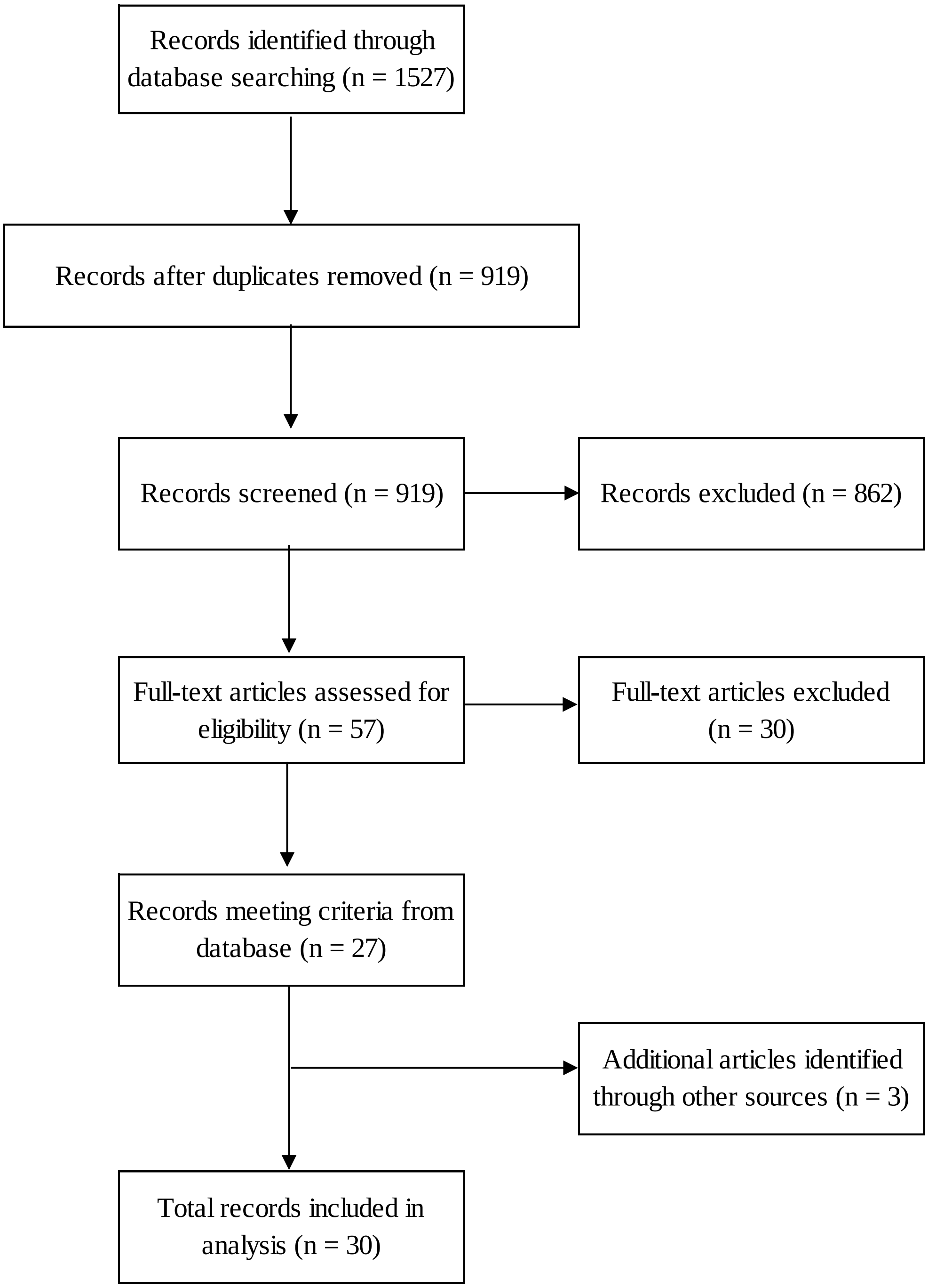

Figure 2.1. PRISMA diagram of selection of studies.

2.3. Results

Thirty studies in the child and adolescent literature investigated at least one of the three key components of Hirsch and Matthews' cognitive model. Tables 2.1. to 2.3. provide a summary of the studies reviewed. Overall, the quality assessment of articles in the systematic review was moderate to strong, indicating a low risk of bias.

Information-processing Biases

Attention bias. Eight studies examined the association between attention biases and worry or GAD in youth. The studies reviewed show that youth with GAD displayed an attention bias towards threat-related words (Dalgleish et al., 2003; Taghavi, Neshat-Doost, Moradi, Yule, & Dalgleish, 1999) and threat-related angry faces (Waters, Mogg, Bradley, & Pine, 2008; Waters, Bradley, & Mogg, 2014), relative to neutral stimuli, in a Dot-probe task. This pattern of selective attention towards threat was specific to anxious youth with GAD in comparison to non-anxious controls, which suggests that negative attention biases play a role in pathological worry.

However, some studies using the visual Dot-probe task have shown mixed results. One study found that attention bias towards threat was associated with overall anxiety symptoms, although no relationship between threat bias and a diagnosis of GAD, separation anxiety or social phobia emerged (Roy et al., 2008). Similarly, another study showed that threat bias was positively associated with social anxiety and social phobia, but not with GAD, panic or separation anxiety (Abend et al., 2017). Both studies utilised samples drawn from multi-site designs, which provide certain advantages such as aggregating large, heterogeneous samples that increase statistical power and generalisability. However, some limitations of multi-site designs are the increased variability of the combined data due to lack of control over conditions, different study designs, high comorbidity, and confounding variables. Perhaps for these reasons, it is difficult to isolate associations between attention biases and specific anxiety disorders such as GAD.

Other studies used a modified Stroop task to assess attention biases in youth with worry or GAD. One study (Eschenbeck, Kohlmann, Hem-Dreger, Koller, & Leser, 2004) examined the Stroop effect in children with high worry, by presenting happy and angry faces in random colours and measuring reaction times and errors to verbal colour-naming responses. The results demonstrated that high worriers produced more errors in colour-naming responses, especially in relation to negative emotional faces, in comparison to low worriers. Similarly, another study (Taghavi, Dalgleish, Moradi, Neshat-Doost, & Yule, 2003) demonstrated a Stroop effect in a clinical sample of youth with GAD, using positive, neutral, depressed, threat, and trauma related words. Children and adolescents with GAD showed a strong colour-naming interference effect for negative emotional words relative to the control group, suggesting evidence of a negative attention bias in pathological worriers.

In contrast, Dalgleish et al. (2003) using the same modified Stroop task with emotionally valanced words, found no significant differences between depressed, GAD, PTSD or control groups. Furthermore, in the same study, youth with GAD showed an attention bias for threat on the Dot-probe task, but not on the modified Stroop task. Interestingly, there was no correlation between these two tasks, indicating that they may be measuring different aspects of attention bias. Overall, the results suggest that youth with GAD show an attention bias towards threat, however the findings are mixed.

Interpretation bias. Four studies assessed the relationship between interpretation biases and worry or GAD in children and adolescents. One study (Taghavi, Moradi, Neshat-

Doost, Yule, & Dalgleish, 2000) showed that youth with GAD were more likely to interpret the meaning of ambiguous homograph words (e.g. hang) as threatening as opposed to neutral, in a sentence generation task, whereas non-anxious controls did not show this bias. Furthermore, Bogels, Snieder, and Kindt (2003) examined the specificity of interpretation biases across children with symptoms of social phobia, separation anxiety, and GAD. Children were presented with nine ambiguous vignettes describing situations related to separation, social, and generalized anxiety and were instructed to give their interpretations of the scenarios. Overall, high anxious children reported ambiguous scenarios as more dangerous and threatening compared to low anxious controls, however there was no evidence that children with GAD symptoms showed content specificity for interpretations related to generalised anxiety. The authors suggest that this is perhaps a reflection of comorbidity within the sample and the nature of the disorder, which is characterised by general worry rather than worry concerning specific situations. Nevertheless, both studies indicate that clinically anxious youth with GAD display a greater tendency to interpret ambiguous information as threatening compared to controls.

These results are consistent with evidence in non-clinical children with varying levels of worry. Suarez and Bell-Dolan (2001) found that high worriers compared to low worriers, as measured with the Penn-State Worry Questionnaire for Children (PSWQ-C), interpreted both ambiguous and threatening scenarios as threatening, expressed more worry in response to the scenario, and exaggerated the probability of future negative events happening to them. In addition, Suarez-Morales and Bell (2006) examined the link between worry, interpretation biases, socio-economic status, and gender in an ethnically diverse community sample. The study found that worry was associated with negative interpretations of ambiguous and threatening scenarios, whilst stressful life experiences, gender, and socio-economic status were important factors in how children interpreted information. Overall, evidence indicates that interpretation biases are associated with child and adolescent worry.

Memory bias. Only one study has investigated the association between memory bias and GAD in youth. Dalgleish et al. (2003) found no significant differences between youth diagnosed with GAD, PTSD, depression, and controls, when comparing memory recall of words that were related to threat, depression, trauma, happy, and neutral. Whilst this study suggests that memory biases are not related to worry or GAD in youth, further research examining the relationship between memory bias and worry is needed to draw further conclusions.

Executive Functions

Attentional control. Six studies examined the relationship between attentional control and worry or GAD in youth. A common measure of attentional control was the Shift subscale of the Behavior Rating Inventory of Executive Function – Parent Form (BRIEF). The BRIEF, composed of eight subscales, captures different aspects of executive functions such as inhibition, shifting, emotion regulation, initiating, working memory, planning, organisation, and monitoring. One study showed that deficits on all eight dimensions of the BRIEF were associated with high worry in children (Geronimi, Patterson, & Woodruff-Borden, 2016). Furthermore, age moderated this relationship in younger children, whilst attentional control, inhibition, and emotion regulation had a more stable association with worry across ages. This suggests that executive functions related to behavioural and self-regulation processes may be more important in maintaining worry.

In line with these findings, one study showed that poor emotion regulation and attentional control were associated with elevated GAD symptoms in children exposed to community violence (Burgers & Drabick, 2016). Moreover, executive functions moderated the relationship between GAD and community violence exposure, where children with poor attentional control and emotion regulation deficits showed more elevated symptoms of GAD when they were exposed to high levels of direct victimisation. This suggest that improving emotion regulation skills or cognitive control may be useful in reducing pathological worry in vulnerable populations. Other studies investigated the impact of attentional control on child temperament and worry. The studies demonstrated that attentional control moderates or mediates the association between worry and challenging temperaments such as emotional reactivity (Gramszlo & Woodruff-Borden, 2015), fearfulness (Gramszlo, Geronimi, Arellano, & Woodruff-Borden, 2017), behavioural inhibition (Sportel, Nauta, de Hullu, de Jong, & Hartman, 2011), and negative affect (Verstraeten, Bijttebier, Vasey, & Raes, 2011). Together, these studies indicate that attention control may be an important mechanism underlying pathological worry in youth.

Working memory. Four studies examined the relationship between worry and working memory in youth. One study showed that poor working memory was associated with high worry in children, as measured with the BRIEF questionnaire (Geronimi et al., 2016). Similarly, adolescent studies have found that worry influences working memory capacity in relation to academic performance (Trezise & Reeve, 2014, 2016). Working memory was assessed using a novel Algebraic Working Memory task, which involved solving equations and recalling algebraic terms. The studies showed that low working memory was associated with high worry, whilst high working memory was associated with low worry, and this relationship remained stable over time. Furthermore, another study (Owens, Stevenson, &

Hadwin, 2012) used the digit span and spatial span tasks, to demonstrate that high worry interfered with working memory in adolescents, which lead to lowered academic performance. Together, the studies reviewed provide evidence to suggest that impaired working memory is associated with high worry in children and adolescents.

Emotion regulation. Six studies investigated the relationship between deficits in emotion regulation and worry or GAD in youth. The studies found that poor emotion regulation was associated with elevated worry and symptoms of GAD (Burgers & Drabick, 2016; Geronomi et al., 2016). Moreover, emotion regulation mediated the relationship between worry and emotionally reactive child temperaments (Gramszlo & Woodruff-Borden, 2015) and perfectionism (Affrunti & Woodruff-Borden, 2017). These studies suggest that emotion regulation during childhood is related to the development of worry, as children with high worry tend to display a decreased ability to control their emotions.

Similarly, one study in adolescents (Mathews, Kerns, & Ciesla, 2014) showed that symptoms of GAD were associated with lack of emotional clarity, difficulties in accepting emotions, negative self-evaluations on managing emotions, and reacting to emotions more negatively. This indicates that emotional regulation deficits are associated with adolescent worry and may be important processes to target for interventions. Interestingly, another study (Suveg, Sood, Comer, & Kendall, 2009) demonstrated that anxious youth who received CBT, which included one session focused on recognition and understanding of emotions, showed significant improvements in emotion regulation skills in terms of coping with worry at post-treatment. Overall, these studies suggest that emotion dysregulation is associated with the development worry in youth**.**

Verbal Processing of Worry

Verbal worry. Six studies examined the verbal nature of worry in youth. Two studies (Szabó, 2007; Carr & Szabó, 2015) used a modified version of The Child and Adolescent Worry questionnaire, where children rated the extent to which they worry, are afraid of, or think about a list of negative outcomes. Szabó (2007) found that worry in children was strongly associated with fear, whereas in adults, worry was uniquely associated with verbal thought processes. Similarly, Carr & Szabó (2015) showed that children associated worry more strongly with fear, however this relationship was moderated by age, as older children reported that their worry was more closely related to thinking processes. Both studies suggest that the nature of worry differs for children and adults, as worry in children is primarily a fear response, but may involve intrusive thoughts at later stages of development.

In adolescents, studies showed an association between worry and cognitive avoidance (Fialko et al., 2012; Frala, Mischel, Knapp, Autry, & Leen-Feldner, 2014; Gosselin et al., 2007; Laugesen, Dugas, & Bukowski, 2003). Cognitive avoidance is described as an automatic process of avoiding threatening mental imagery and effortful strategies to supress unwanted thoughts. One study (Gosselin et al., 2007) showed that the cognitive avoidant strategy of transforming images into verbal thoughts was not associated with worry. This finding suggests that this strategy is less prevalent in adolescents as it perhaps involves abstract processes that adolescents are not fully conscious of using. Similarly, an experimental study using a worry induction (Frala et al., 2014) found no evidence of the verbal-linguistic nature of worry in adolescents. Overall, the studies reviewed suggest that worry in children and adolescents may not reflect the same verbal worry processes as those observed in adults.

Table 2.1

Summary of Studies on Information Processing Biases associated with Child and Adolescent Worry

Study	n	% Girls	Age	Diagnosis	Factor	Task	Stimulus used	Outcome measures
Abend et al. (2017)	1291	56	6-18	Mixed clinical and community sample	Attention Bias	Dot Probe Task	Visual stimuli of angry and neutral faces	SCARED
Bogels et al. (2003)	96	68	7-12	GAD (n = 20), SA (n = 15), SAD (n = 20), Control (n = 41)	Interpretation Bias	Ambiguous Stories	Ambiguous vignettes related to social, separation, and general anxiety scenarios	Ratings and questions related to the interpretation of the scenario
Dalgleish et al. (2003)	93	53	7-18	GAD (n = 24), MDD (n = 19), PTSD (n = 24), Control (n = 26)	Attention Bias	Dot Probe Task	Words related to threat and depression	BPVS; DSRS; RCMAS; The Subject Probability Questionnaire; WORD
						Modified Stroop Task	Words related to threat, depression, trauma, positive, and neutral	
					Memory Bias	Memory Task	Words related to threat, depression, trauma, positive, and neutral	

Table 2.1 (continued)

Study	n	% Girls	Age	Diagnosis	Factor	Task	Stimulus used	Outcome measures
Eschenbeck et al. (2004)								
Study 1	92	43	7-8	Community sample	Attention Bias	Modified Stroop Task	Visual stimuli of angry and happy faces	AFS; WEQ
Study 2	63	59	7-10	Community sample		Modified Stroop Task		AFS; WEQ
Study 3	225	52	6-10	Community sample		Modified Stroop Task		AFS; WEQ
Roy et al. (2008)	152	47	7-18	Anxious (n = 101) [GAD, SP, SAD], Control (n = 51)	Attention Bias	Dot Probe Task	Visual stimuli of angry, happy, and neutral faces	ADIS-IV-C; K-SADS-P; MASC; PARS; SCARED; WISC-III
Suarez & Bell-Dolan (2001)	277	56	10-12	Community sample	Interpretation Bias	The Children's Opinions of Everyday Life Events (COELE)	Ambiguous and threatening vignettes related to family, relationships, school, performance, health, and personal harm	Ratings and questions related to the interpretation of the scenario
Suarez-Morales & Bell (2006)	292	51	10-11	Community sample	Interpretation Bias	The Children's Opinions of Everyday Life Events - Revised (COELE-R)	Ambiguous and threatening vignettes related to family, relationships, school, performance, health, and personal harm	RCMAS; PSWQ-C; LEC; DHQ

Table 2.1 (continued)

Study	n	% Girls	Age	Diagnosis	Factor	Task	Stimulus used	Outcome measures
Taghavi et al. (1999)	67	51	9-18	GAD (n = 24), Mixed anxiety-depression (n = 19), Control (n = 24)	Attention Bias	Dot Probe Task	Words related to physical threat, social threat, and depression	BPVS; DSRS; RCMAS; WORD
Taghavi et al. (2000)	57	42	8-17	GAD (n = 17), Control (n = 40)	Interpretation Bias	Homograph sentence generation task	Words related to threat and neutral	BPVS; DSRS; RCMAS; WORD
Taghavi et al. (2003)	38	53	*M* = 14	GAD (n = 19), Control (n = 19)	Attention Bias	Modified Stroop Task	Words related to threat, depression, trauma, happy,	BPVS; DSRS; RCMAS; WORD
Waters et al. (2008)	48	44	7-12	GAD (n = 23), Control (n = 25)	Attention Bias	Dot Probe Task	Visual stimuli of happy, angry, and neutral faces	ADIS-C/ADIS-P; SCAS
Waters et al. (2014)	435	52	5-14	GAD (n = 75), SAD (n = 65), SA (n = 18), SP (n = 75), Control (n = 202)	Attention Bias	Dot Probe Task	Visual stimuli of happy, angry, and neutral faces	ACQ-C; ADIS-IV-C/P; CASI; SCAS; STAI-C; WISC-R; WRMT-R

Note. **GAD** = Generalized Anxiety Disorder; **SAD** = Social Anxiety Disorder; **SA** = Separation Anxiety Disorder; **SP** = Specific Phobia; **PTSD** = Post Traumatic Stress Disorder; **MDD** = Major Depressive Disorder

[a] **ACQ-C** = The Anxiety Control Questionnaire-Child; **ADIS-C/ADIS-P** = The Anxiety Disorders Interview Schedule for DSM-IV-Child and Parent; **AFS** = Anxiety Questionnaire for Pupils-Manifests Anxiety subscale; **BPVS** = The British Picture Vocabulary Scale; **CASI** = Children's Anxiety Sensitivity Inventory; **DSRS** = The Depression Self-rating Scale; **K-SADS-P** = Schedule for Affective Disorders and Schizophrenia for School-age Children- Present and Lifetime Version; **LEC** = The Life Events Checklist; **MASC** = Multidimensional Anxiety Scale for Children; **PARS** = Paediatric Anxiety Rating Scale for Children; **RCMAS** = Revised Children's Manifest Anxiety Scale; **SCARED** = Screen for Anxiety and Related Disorders; **SCAS** = Spence Children's Anxiety Scale; **STAI-C** = State Trait Anxiety Inventory for Children; **WEQ** = Worry Emotionality Questionnaire-Worry and Emotionality subscale; **WISC-III** = Wechsler Intelligence Scale for Children-Vocabulary and Block design subscales; **WISC-R** = Wechsler Intelligence Scale for Children-Revised; **WORD** = The Basic Reading subtest of the Wechsler Obective Reading Dimensions; **WRMT-R** = Woodcock Reading Mastery Test-Revised

Table 2.2

Summary of Studies on Executive Functions associated with Child and Adolescent Worry

Study	n	% Girls	Age	Diagnosis	Factor	Task/ Questionnaire	Stimulus/ Subscale	Outcome measures
Affrunti & Woodruff-Borden (2017)	66	50	7-13	Community sample	Emotion regulation	BRIEF	Emotion control	BRIEF; CAPS; PSWQ-C
Burgers & Drabick (2016)	104	50	7-11	Community sample	Attentional control	BRIEF	Shift	BRIEF; CASI-4R & YI-4; CEQ; FSIQ
					Emotion regulation		Emotion control	
Geronimi et al. (2016)	130	43	7-12	Community sample	Attentional control	BRIEF	Shift	BRIEF; BAI-Y; BDI-Y; BRIEF; PSWQ-C
					Emotion regulation		Emotion control	
					Working memory		Working memory	
Gramszlo & Woodruff-Borden (2015)	99	40	7-10	Community sample	Attentional control	BRIEF	Shift	BRIEF; PSWQ-C; TMCQ
					Emotion regulation		Emotion control	
Gramszlo et al. (2017)	152	44	7-12	Community sample	Attentional control	BRIEF	Shift	BRIEF; BAI-Y; PSWQ-C; TMCQ

Table 2.2 (continued)

Study	n	% Girls	Age	Diagnosis	Factor	Task/ Questionnaire	Stimulus/ Subscale	Outcome measures
Matthews et al. (2014)	90	50	11-14	Community sample	Emotion regulation	DERS	Awareness; Clarity; Non-acceptance	COPE; DERS; Parent-child interactions; SAS-A; SCARED
Owens et al. (2012)								
Study 1	88	55	12-13	Community sample				CTAS; NCSAT; RCADS; STAI
Study 2	31	52	12-13	Community sample	Working memory	Digit Span Task	Digits	CTAS; NCSAT; RCADS; SATs; STAI;
						Spatial Span Task	Geometric shapes	
Sportel et al. (2011)	1806	55	*M* = 13.6	Community sample	Attentional control	ATQ	Attentional control; Effortful control	ATQ; BIS/BAS
Suveg et al. (2009)	37	41	7-15	GAD (n = 27), SA (n = 12), SAD (13)	Emotion regulation	CBT	16 sessions - one session focused on emotion regulation	ADIS-IV-C/P; CEMS; CQ-C; EESC; MASC

Table 2.2 (continued)

Study	n	% Girls	Age	Diagnosis	Factor	Task/ Questionnaire	Stimulus/ Subscale	Outcome measures
Trezise & Reeve (2014)	80	100	14	Community sample	Working memory	Algebraic Working Memory Task	Alphanumeric symbols and algebraic statements	Algebraic Working Memory Task; Algebraic Judgement/Worry Task; Algebra Problem Solving Task; FAS; SPM
Trezise & Reeve (2016)	133	30	14	Community sample	Working memory	Algebraic Working Memory Task	Alphanumeric symbols and algebraic	Algebraic Working Memory Task; Algebraic Judgement/Worry Task; Algebra Problem Solving
Verstraeten et al. (2011)	138	53	9-13	Community sample	Attentional control	ACS ECS		ACS; CDI; CRSQ; ECS; PANAS; PSWQ-C; SCARED-R

Note. **GAD** = Generalized Anxiety Disorder; **SAD** = Social Anxiety Disorder; **SA =** Separation Anxiety Disorder

[a] **ACS** = Attentional Control Scale; **ATQ** = Adult Temperament Questionnaire; **BAI-Y** = Beck Anxiety Inventory-Youth; **BIS/BAS =** Behavioral Inhibition System/Behavioral Activation System Scales; **BDI-Y** = Beck Depression Inventory - Youth; **BRIEF** = The Behavior Rating Inventory of Executive Function-Parent; **CAPS** = The Child and Adolescent Perfectionism Scale; **CASI-4R & YI-4** = DSM rating scales for GAD; **CBT** = Cognitive Behavioural Therapy; **CDI** = Children's Depression Inventory; **CEMS** = Children's Emotion Management Scales; **CEQ** = Community Experiences Questionnaire; COPE = Cope Inventory; **CRSQ** = Children's Response Styles Questionnaire; **CTAS;** Children's Test Anxiety Scale; **DERS** = Difficulties in Emotion Regulation Scale; **ECS** = Effortful Control Scale; **FAS** = The Faces Anxiety Scale; **FSIQ** = Full Scale-2 Intelligence Quotient; **NCSAT** = National Curriculum Standard Assessment Tests; **PANAS** = Positive Affect and Negative Affect Scales; **PSWQ-C** = Penn State Worry Questionnaire-Child; **RCADS** = Revised Child Anxiety and Depression Scale; **SAS-A** = Social Anxiety Scale for Adolescents; **SCARED-R** = Screen for Child Anxiety-Related Emotional Disorders-Revised; **SPM** = Raven's Standard Progressive Matrices; **STAI** = The State-Trait Anxiety Inventory; **SATs** = school scores based on sub-levels of the Key Stage 2; **TMCQ** = Temperamentin Middle Childhood Questionnaire; **WRAT4** = The Wide Range Achievement Test–Fourth Edition

Table 2.3

Summary of Studies on the Verbal Processing of Worry in Children and Adolescents

Study	n	% Girls	Age	Diagnosis	Factor	Questionnaire	Subscale	Outcome measures
Carr & Szabó (2015)	93	48	7-12	Community sample	Verbal worry	CAWS	Fear; Think	CAWS; MCQ-C
Fialko et al. (2012)	515	53	7-19	Community sample	Cognitive Avoidance	CAQ		[a]CAQ; [a]IUS; MASC-10; PSWQ-C; [a]WW2
Frala et al. (2014)	40	52	12-17	Community sample	Verbal worry	FOVLAS-C	VAS	FOVLAS-C; LRT; PANAS-CN; PSWQ-C; SAM; SUDS
Gosselin et al. (2007)	777	50	12-19	Community sample	Cognitive Avoidance	CAQ	Transformation of images	CAQ; PSWQ-C; WWQ

Table 2.3 (continued)

Study	n	% Girls	Age	Diagnosis	Factor	Questionnaire	Subscale	Outcome measures
Laugesen et al. (2003)	528	49	14-18	Community sample	Cognitive Avoidance	WBSI	Thought supression	PSWQ-C; SPSI-RSF; WAQ; WBSI; WW2
Szabó (2007)	70	51	*M* = 9.13	Community sample - children	Verbal worry	CAWS	Fear; Think	CAWS; PSOQ
	45	56	*M* = 19.27	Community sample - adults				

Note. **CAQ** = Cognitive Avoidance Questionnaire; **CAWS** = The Child and Adolescent Worry Scale-Revised; **LRT** = Logical Reasoning Test; **FOVLAS-C** = Future-Oriented/Verbal-Linguistic Visual Analog Scale for Children; **IUS** = Intolerance of Uncertainty Scale; **MASC-10** = Multi-dimensional Anxiety Scale for Children; **MCQ-C** = The Metacognitions Questionnaire for Children; **PANAS-CN** = Positive and Negative Affect Schedule-Child; **PSOQ** = Physical Social Outcome Questionnaire; **PSWQ-C** = Penn State Worry Questionnaire-Child version; **SAM** = Self-Assessment-Manikin Scales; **SPSI-RSF** = Social Problem Solving Inventory-Revised Short Form; **SUDS** = Subjective Units of Distress Scale; **WAQ** = Worry and Anxiety Questionnaire; **WBSI** = White Bear Suppression Inventory; **WW2** = Why Worry II; **WWQ** = Why Worry Questionnaire

[a] Brief 5 item measures of the IUS, CAQ and WW2 were created for the study

2.4. Discussion

The systematic review examined existing evidence for the three building blocks of Hirsch and Matthews' cognitive model of pathological worry in children and adolescents, and evaluated the applicability of the model in understanding worry in youth. Firstly, the review found that cognitive biases were associated with worry and GAD in children and adolescents. Evidence suggests that youth with high worry and GAD display greater threat interpretations of ambiguous information compared to non-anxious youth, whilst there was limited support for a memory bias towards threat. Evidence for a selective attention bias towards threat in children and adolescents with GAD was mixed.

Several factors may contribute to the inconsistent findings of a threat-related attention bias in youth with GAD. One issue is the methodological differences across studies that use various paradigms and task parameters in attention bias research (Bar-Haim et al., 2007; Dudeney et al., 2015). This limits the comparability between studies and reduces statistical power, which highlights the need to standardise tasks across studies to find meaningful effects. A second issue that may contribute to the mixed findings is the reliability of the Dot-probe task and Stroop task, in particular in children. A recent meta-analysis on attention biases in anxious youth, found that differences in processing threat was strongly moderated by age, with a threat-bias more common in younger anxious children (Dudeney et al., 2015). A limitation in paediatric anxiety is that studies often pool together child and adolescent age groups, making it difficult to disentangle age related effects, and perhaps threat-related attention biases in youth with GAD are more prominent at various stages of development.

Furthermore, the mixed findings may be a result of different cognitive tasks tapping into separate aspects underlying attentional processing (Cisler & Koster, 2010; Dalgleish et al., 2003; Klein, de Voogd, Wiers, & Salemink, 2017). It has been suggested that the Dot-probe task captures different aspects of attentional processing, such as attention towards the location of a probe at any given time and the ability to dwell or shift away from this location, whereas the modified Stroop task measures other aspects of attentional processing that show less specificity and may be explained in terms of response competition (Fox, Russo, & Dutton, 2002). Future research examining attention biases in children and adolescents should aim to improve the reliability of tasks, use standardised measures across studies, and examine age related effects to help overcome some of the challenges in the field (Kruijt, Field, & Fox, 2016; Parsons, Kruijt, & Fox, 2018). Overall, evidence in the current review provides preliminary support for the first building block of Hirsch and Matthews' cognitive model of pathological worry in understanding worry in youth. However, the results are mixed, and further investigation of how worry relates to attention, interpretation, and memory biases are needed.

Secondly, the current review found evidence that impaired executive functions were associated with worry in youth. Consistent with the adult literature, studies showed that poor attentional control, reduced working memory capacity, and deficits in emotion regulation were related to high worry and GAD in children and adolescents. Together, these studies indicate that executive functions may play a role in the process of worry in youth and provides support for the second building block outlined in Hirsch and Matthews' cognitive model. Future experimental designs would offer further insights into the causal relationship between deficits in executive functions and child and adolescent worry.

Finally, the current review found little evidence for the verbal nature of worry in children and adolescents, suggesting that worry may not reflect the same verbal processes as those typically observed in adults. The studies reviewed indicate that children between the ages of seven and twelve experience worry as physiological arousal symptoms and mental based imagery closely associated with fear, as opposed to verbal thoughts reported in older children and adults. Similarly, there was limited evidence of the verbal-linguistic nature of worry in adolescents, which suggests that worry reflects cognitive developmental changes and adolescence may be an important transition period where the nature of worry shifts into a more thinking like processes.

These findings support Vasey's model of worry (1993), which proposes that the ability to switch from mental imagery to verbal worry is a cognitive skill that develops with age. Whilst Vasey argues this transition occurs from middle childhood onwards, the findings in the current review did not support this. It is unclear at what age worry acquires the characteristics of verbal thoughts and its associated cognitive avoidance response. Future studies should address this gap and investigate whether worry in youth reflects imagery-based or verbal processes, which may help develop more targeted interventions. Therefore, the current review found evidence for two of the building blocks outlined in Hirsch and Matthews' cognitive model of pathological worry in youth. However, there was little support that youth experience worry in verbal form, which perhaps reflects more advanced stages of cognitive development. Thus, it is important that research investigating the nature of worry in youth integrates a developmental framework to highlight that a child is continuously changing and evolving over time (Kertz & Woodruff-Borden, 2011), which would provide a clear focus for future research and advance understanding in this field.

2.4.1. A cognitive model of child and adolescent worry

The applicability of Hirsch and Matthews' model (2012) to children and adolescents is yet to be empirically tested and it is not clear whether these cognitive factors, which have been well supported in the adult literature, operate during child and adolescent worry and at what developmental stage they begin to play a role. To facilitate a programme of research on these important gaps in the literature and a framework for the studies presented in this thesis, we propose a cognitive model of child and adolescent worry based on Hirsch & Mathews' cognitive model (2012) to help guide future research in understanding the cognitive mechanisms underlying worry in youth. The model is described below and illustrated in Figure 2.2.

We propose that child and adolescent worry is associated with negative cognitive biases, deficits in executive control processes, poor emotion regulation, intolerance of uncertainty, and maladaptive metacognitive beliefs. In addition, we emphasise that these cognitive processes are all influenced by developmental factors, such as age, cognitive, social, and emotional development, which are vital components to the trajectory of worry throughout childhood and adolescence.

The model begins by hypothesising that worry is preceded by a situation or an initial trigger, which may be internal, such as an intrusive thought, or an external event such as an everyday stressor. When a certain situation or trigger arises, involuntary 'bottom up' processes such as attention biases towards threatening cues, negative interpretation biases of ambiguous information, or negative memory biases, lead to the representation of threat initially entering into awareness. Subsequently, 'top down' executive control processes, such as attentional control or working memory, interacts with these cognitive biases to determine whether a worry episode manifests. In the long term, worry can become excessive and develop into pathological worry or anxiety through maintaining factors such as poor emotion regulation skills, intolerance of uncertainty, and negative metacognitive beliefs about worry.

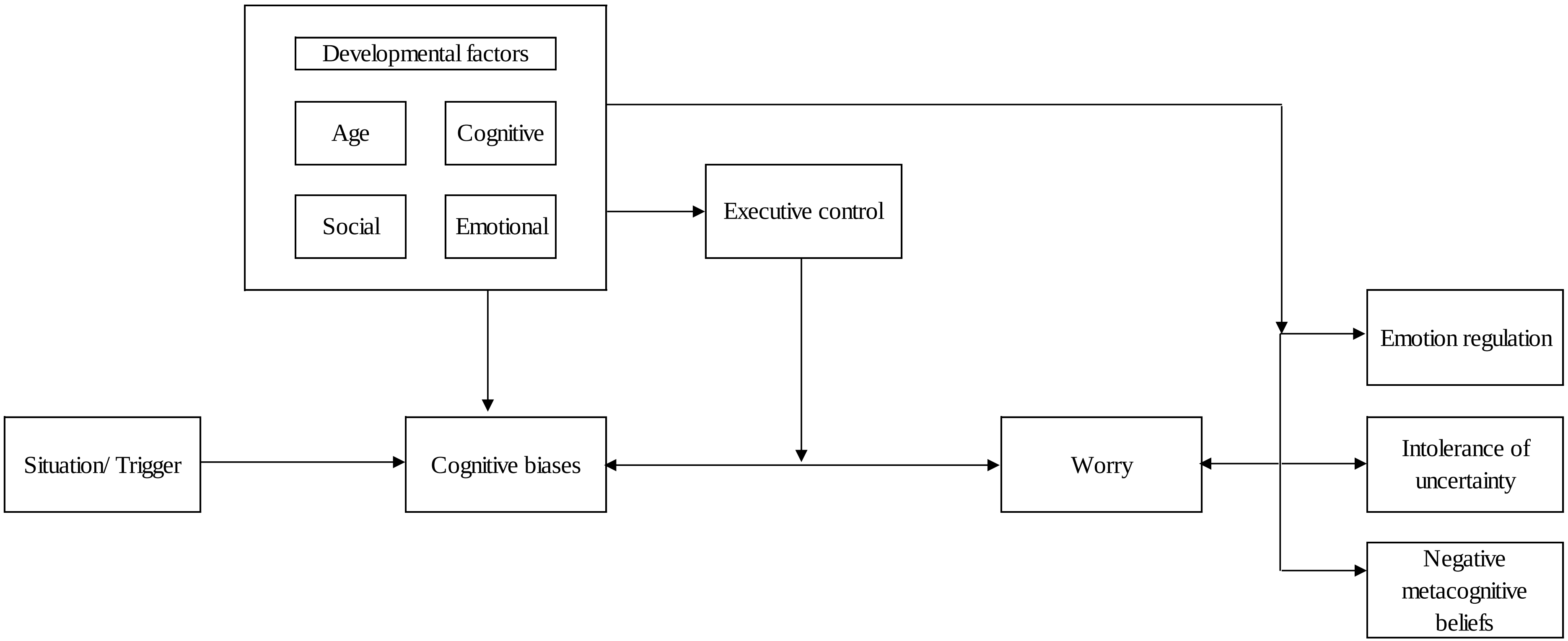

Figure 2.2. Cognitive model of child and adolescent worry.

Firstly, evidence in the current systematic review indicates that cognitive biases, such as attention and interpretation, are associated with worry in youth. These maladaptive cognitive biases typically occur without awareness and are involuntary processes that are likely to be re-enforced over time through habitual thought patterns, which become activated when future triggers are encountered. Thus, in our model, a worry-prone child or adolescent may have the tendency to make threatening interpretations and are likely to direct their attention towards potentially negative outcomes when faced with an uncertain future event or ambiguous situation. In the proposed model, the direct relationship between cognitive biases and worry is yet to be examined, with the majority of research focused on anxiety disorders and only two studies conducted on outcomes of worry (Suarez & Bell-Dolan, 2001; Suarez-Morales & Bell, 2006). There is a need for future studies to investigate the role of cognitive biases in child and adolescent worry, in particular in non-clinical samples, to examine the trajectory of worry before it manifests in GAD. In addition, longitudinal studies examining the causal relationship between cognitive biases and worry in youth would help to identify the cognitive mechanisms to target in early interventions.

Secondly, we hypothesise that deficits in executive control impairs children and adolescent's ability to redirect attention away from negative intrusions. The current review found promising results that worry is associated with deficits in attention control and working memory capacity in youth. In line with Hirsch & Mathews' (2012) cognitive model of pathological worry, we propose that high worriers may have insufficient executive control to override negative intrusions and are less able to redirect their thoughts away from negative information once it enters into awareness. We hypothesise that 'top-down' executive control processes, such as attentional control or working memory, moderate the association between cognitive biases and worry. For instance, in low worriers, when a representation of threat enters into awareness through 'bottom-up' influences of cognitive biases, children and adolescents with greater executive control are able to inhibit the negative intrusion from developing into a worry episode. In contrast, impairments in executive control in high worriers make it difficult to ignore negative intrusions, which leads to uncontrollable and repetitive worry. Future experimental studies investigating the impact of active worry on executive functions such as working memory capacity, attentional control, or cognitive flexibility would help to identify how executive control processes contribute to worry.

Thirdly, the model outlines the importance of developmental factors that contribute to worry in children and adolescents. We propose that developmental factors such as age, cognitive, social, and emotional changes have a large impact on the development of cognitive biases and executive functions, which in turn influences the way worry is experienced by children and adolescents. In our proposed model, cognitive, social, and emotional development captures many aspects of growth that affect how a child or adolescent interacts with their environment. These developmental factors relate to changes in cognitions, learning capabilities, problem-solving abilities, expressing and controlling emotions, temperament, social skills, interacting with peers, as well as establishing and maintaining relationships. These developmental changes may be important in shaping the way cognitive biases and executive control processes operate and become habitual patterns over time. There are limited studies that have examined how cognitive biases and executive functions develop throughout the lifespan, in particular in relation to worry. Therefore, we have included a developmental element to our cognitive model of worry to provide a framework for future studies to consider how developmental changes may influence child and adolescent worry.

To our knowledge, there have been no studies that have examined how executive functions or attention, interpretation, and memory biases develop throughout childhood and adolescents in relation to outcomes of worry. Only one correlational study has shown that age moderates the relationship between worry and executive functions in children (Geronimi et al., 2016). Whilst, recent reviews suggest that the association between negative interpretation biases and anxious youth increases with age (Stuijfzand et al., 2017) and negative attention biases in anxious children varies across childhood (Dudeney et al., 2015). In line with the combined cognitive bias hypothesis (Hirsch, Clark, & Matthews, 2006), we propose that during childhood and adolescence, cognitive biases and executive functions might operate more closely together and are interlinked with ongoing developmental changes, however as cognitive processes become more habitual over time, these biases may become more independent and certain biases and executive functions become more significant than others. Future studies investigating the interrelationships amongst cognitive biases and executive functions and how these processes evolve over time would provide a deeper understanding of how developmental factors impact the nature of worry in children and adolescents.

In line with the findings of the current review, we propose that the nature of worry in youth differs to the verbal worry experienced by adults. We hypothesise that negative intrusions in youth may take the form of thoughts, images or impressions depending on the child's age, cognitive, social or emotional development. Further research on whether worry in youth is a verbal process or imagery based would provide more targeted approaches to early interventions for worry and improve current treatments. This illustrates that cognitive models of adult worry may not be fully appropriate for younger populations and a developmentally sensitive model of worry in children and adolescents is needed.

Finally, consistent with Hirsch and Matthews' model, we propose that emotion regulation, intolerance of uncertainty, and metacognitive beliefs are a consequence of worry, rather than a causal mechanism. We hypothesise that intolerance of uncertainty and emotion dysregulation contributes to the maintenance of worry in youth. Once the repetitive and intrusive nature of worry is established, high worriers are more likely to find it difficult to recognise and manage their emotions, which in the long-term develops into a repetitive cycle of pathological worry. On the other hand, individuals who are able to effectively regulate their worrisome thoughts learn adaptive behaviours that enable them to cope with worry. In addition, we include negative metacognitive beliefs in our model as a factor that maintains the worry process in youth, as there is more evidence to suggest that negative beliefs about the harmful nature of worry are a stronger risk factor for worry in youth compared to positive beliefs about worry (Ellis & Hudson, 2010). Together, emotional dysregulation, intolerance of uncertainty, and negative metacognitive beliefs maintain the worry cycle, and importantly, are processes influenced by age, cognitive, social, and emotional development.

In summary, we propose that the combined effects of negative cognitive biases, deficits in executive control, poor emotion regulation, intolerance of uncertainty, and maladaptive metacognitive beliefs about worry may help to explain how information is processed during worry in children and adolescents. We acknowledge that these cognitive vulnerability factors interact with each other and change over time, with the influence of cognitive, social, and emotional development across childhood and adolescence. Examining these associations longitudinally in healthy populations would provide useful insight into how cognitive development is related to worry, as well as how these cognitive factors may interact with one another to influence worry over time. Furthermore, the model would provide additional knowledge into the cognitive pathways from worry to anxiety disorders, as well as insight into the protective factors that contribute to resilience to worry.

The current systematic review should be considered in light of its strengths and limitations. One limitation to the review and to the literature in general, is that the majority of studies are correlational in design and do not address the causal direction between worry and the cognitive processes of interest. Another limitation is that the studies reviewed often combine a wide age range of children and adolescents, making it difficult to disentangle age related effects, and it may be that some cognitive processes are not fully developed in certain age groups. To the best of our knowledge, this was the first systematic review to evaluate the applicability of Hirsch and Matthews' cognitive model of worry to younger populations and investigate the association of cognitive biases, executive functions, and verbal worry in youth with high worry or GAD. Our cognitive model of child and adolescent worry is intended to provide a theoretical framework that may help guide future research on the underlying mechanisms that play a causal role in worry in youth. These pathways provide testable hypothesis and a research framework for the studies presented in this thesis, which may help to identify the mechanisms to target in early interventions and treatments for worry.

Evidence in the current review suggests that reducing the impact of negative cognitive biases and improving executive control are potential cognitive processes to target for worry in youth. Recent studies have shown promising results that working memory training in high worriers predicted improvements in working memory capacity and reduced levels of worry symptoms (Voogd, Wiers, Zwitser, & Salemink, 2016; Grol et al., 2018; Hotton, Derakshan, & Fox, 2018). Moreover, studies that improve emotion regulation skills have shown to reduce the negative emotions experienced by youth with GAD (DeWitte, Sutterlinb, Braetd, & Muellera, 2017; Suveg et al., 2009). Together, these studies suggest that targeting executive functions may increase the ability to control worrisome thoughts and could be a valuable addition to improving current treatments.

Furthermore, the current review found consistent evidence for the association between interpretation bias and worry in youth. This is in line with a recent systematic review and meta-analysis, which found an overall medium positive association (cohen's $d = 0.62$) between negative interpretation biases and anxious children and adolescents (Stuijfzand et al., 2017). Evidence suggests that perhaps Cognitive Bias Modification of Interpretations (CBM-I) is a promising training intervention that uses simple learning mechanisms to encourage individuals to endorse benign rather than negative resolutions to ambiguous cues. Several studies have examined CBM-I training in youth with mixed findings (Lau, 2013; Lau, 2015; Krebs et al., 2018). Further investigation is needed to evaluate the efficacy of CBM-I training in youth with GAD or elevated symptoms of worry. Therefore, there are a number of cognitive factors that could potentially be targeted in interventions for reducing high worry in youth. However, it is unknown which cognitive processes are the most salient or what would be the best way to target these mechanisms. Further investigation and empirical support is warranted.

The literature on the cognitive mechanisms underlying child and adolescent worry remains largely unexplored. Importantly, future research should integrate a developmental approach to understanding how cognitive, social, and emotional changes influence worry. Longitudinal research and experimental designs would provide useful insight into the causal and maintaining factors of worry in youth and how these processes interact and change over time. Childhood and adolescence is a critical and sensitive period that entails major cognitive, developmental, and physiological changes. Therefore, understanding this phenomenon in children and adolescents is imperative for building emotionally resilient individuals well into adulthood.

Chapter 3

3

The Role of Cognitive Biases in Adolescent Worry

There is a relatively small body of research examining the cognitive mechanisms underlying the development and maintenance of worry in adolescence. This is the first study that investigated the association between cognitive biases and worry in adolescence, in particular, whether attention bias, interpretation bias, and memory bias were related to levels of worry. Participants were 504 healthy adolescents taking part in the CogBias Longitudinal study and data presented was from time point one. The results showed that interpretation and memory bias were associated with worry in adolescents. However, there was no evidence to support an association between worry and attention bias towards threat. Furthermore, we investigated the combined cognitive bias hypothesis to assess whether attention, interpretation, and memory biases are interrelated cognitive processes that influence each other in adolescent worry (Hirsch et al., 2006). The data suggests that interpretation and memory biases are closely interrelated cognitive processes and are associated with worry in adolescence.

3.1. Introduction

Anxiety disorders are the most frequent and debilitating mental disorders in children and adolescents (Beesdo, Knappe, & Pine, 2009; Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015), with estimates indicating that 31.9% of adolescents experience an anxiety disorder in their lifetime (Merikangas et al., 2010). Anxiety in adolescents is associated with impaired psychosocial functioning, poor academic performance, avoidance behaviours, and decreased mental well-being (Essau, Lewinsohn, Olaya, & Seeley, 2014). When left untreated, anxiety often follows a chronic and unremitting course, and is linked to increased risk of developing anxiety disorders, depression, physical illnesses, substance abuse, and other psychopathology in adulthood (Last, Hansen, & Franco, 1997; Pine et al., 1998; Woodward & Fergusson, 2001). Whilst there have been significant advancements in the treatment of anxiety disorders in adolescents, there is a lack of understanding of the cognitive dimensions that contribute to the development and maintenance of anxiety in youth (Alfano, Beidel, & Turner, 2002).

Worry has been defined as one of the core cognitive components of anxiety (Borkovec et al., 1991) and is described as a mental process involving repetitive negative thoughts or images about the uncertainty of future events (Vasey & Daleiden, 1994). Research shows that worry is common in adolescents, with females reporting higher levels and frequencies of worry compared to males (Barahmand, 2008; Caes, et al., 2016; Muris, et al., 2001). Worry can serve as an adaptive response in anticipation to perceived threat (Davey, 1994; Watkins, 2008), however excessive and uncontrollable worry can cause significant distress and is a characteristic of several anxiety disorders, specifically GAD (American Psychiatric Association, 2013). Research has found strong links between worry and anxiety, as studies indicate they are highly correlated constructs (Weems, Silverman, & La Greca, 2000) with subtle cognitive and physiological differences (Craske, 1999; Barlow, 2002). Anxiety is generally conceptualised as a global construct encompassing the interplay between somatic sensations (e.g. palpitations, increased heart rate, and accelerated respiration), cognitive elements (e.g. worry, vigilance, and perception), and behavioural components (e.g. avoidance) that contribute to an active state of fear about future threat (Rabner, Mian, Langer, Comer, & Pincus, 2017).

Late childhood and adolescence have been identified as important periods for the development of worry (Copeland et al., 2014). In particular, adolescence represents a transition phase between childhood and adulthood, marked by major physical, cognitive, social, and emotional changes (Crone, 2009; Dahl & Gunner, 2009). Studies have shown that the complexity, frequency, and elaboration of worry increases from the age of eight onwards due to developmental changes in cognitive ability (Muris et al., 2000, 2002; Vasey & Daleiden, 1994). Vasey and colleagues (1993, 1994) suggest that abstract and formal reasoning skills attained during middle childhood and adolescence are vital to the development of worry, as these cognitive abilities enable individuals to anticipate future events and envision catastrophic possibilities. Despite the clinical importance of worry as a potential cognitive precursor to the development of anxiety, the mechanisms underlying worry in adolescents are not yet fully understood or as well established as the adult literature (Cartwright-Hatton, 2006). Identifying the cognitive risk factors associated with worry in adolescents may help inform better treatments and early interventions for anxiety in youth.

Cognitive theories in adults propose that anxiety disorders are characterised by threat-related information-processing biases (Beck et al., 1985, 1979; Williams et al., 1997). Information-processing biases, also known as cognitive biases, refer to distorted patterns of thinking and ways in which information is processed and perceived. According to Beck's influential cognitive model of anxiety (Beck et al., 1985), anxious individuals hold cognitive schemas related to danger or threat. These schemas are activated when a potential threat is perceived in the environment and lead to excessive hypervigilance for threat, which in turn increases anxiety, resulting in a vicious cycle further increasing hypervigilance. Threat-related cognitive biases are thought to be relatively involuntary processes that play an important role in the aetiology of anxiety disorders (Williams et al., 1997).

A wealth of empirical evidence supports the selective processing of threat in cognitive models of anxiety. Studies have found that anxious adults demonstrate an attention bias towards threat, compared to positive and neutral stimuli, and relative to non-anxious adults (Bradley et al., 1999; Hayes et al., 2010; MacLeod et al., 1986; Mogg, Bradley, & Williams, 1995). In addition, research indicates that anxious adults tend to interpret ambiguous scenarios or stimuli as more threatening compared to non-anxious controls (Eysenck, Mogg, May, Richards, & Mathews, 1991; Hirsch et al., 2009; Matthews & MacLeod, 2005). Furthermore, there is some evidence to suggest that memory biases, the tendency to selectively recall and recognise anxiety-congruent threatening stimuli, is associated with anxiety, however the findings are mixed (Mitte, 2008). Overall, research shows empirical support that threat related cognitive biases are mechanisms that play a role in adult anxiety.

Similarly, cognitive theories of anxiety in children and adolescents propose that anxiety manifests through the selective-processing of threat related information (Crick & Dodge, 1994; Daleiden & Vasey, 1997; Field et al., 2011; Kendall, 1985; Muris & Field, 2008; Murray et al., 2009; Vasey & Daleiden, 1994). Behavioural and eye-tracking studies demonstrate that anxious adolescents show enhanced attention towards threat-related stimuli relative to non-anxious controls (Bar-Haim et al., 2007; Dudeney et al., 2015; Puliafico & Kendall, 2006). A recent meta-analysis found a medium effect size (d = 0.54) for selective attention bias towards threat-related stimuli compared to neutral stimuli in anxious youth, which was significantly greater than an attention bias to threat in control groups (d = 0.15) (Dudeney et al., 2015). However, some of the findings on threat vigilance in anxious youth have been mixed due to reliability issues with attention bias tasks and age related effects amongst youth (Dodd et al., 2015; Shechner et al., 2013, 2017).

In addition to selective attention towards threat, anxious adolescents tend to attribute greater threat interpretations towards ambiguous information, compared to non-anxious controls (Castillo & Leandro, 2010; Stuijfzand et al., 2017). Whilst most research has focused on anxiety, only two studies have examined the direct relationship between interpretation bias and child worry (Suarez & Bell-Dolan, 2001; Suarez-Morales & Bell, 2006). Suarez and Bell-Dolan (2001) presented children with 12 ambiguous and threatening vignettes related to the domains of family, social relationships, school, performance, health, and personal harm. The study found that high worriers compared to non-worriers, as measured with the Penn State Worry Questionnaire (PSWQ-C), interpreted ambiguous and threatening scenarios as more threatening, expressed greater worry in response to the scenarios, and exaggerated the probability of negative events happening to them in the future. Further investigation of the relationship between worry and interpretation biases in adolescents will provide greater insight into the cognitive mechanisms underlying worry during this important developmental period.

Consistent with the adult literature, there are mixed findings that anxious youth show memory biases towards threatening information (Mitte, 2008). One study used a self-referential encoding task to show evidence for a negative memory bias in child social anxiety (Vassilopoulos, 2012). Children were asked to rate a list of words according to how well each word described what others thought of them, followed by a retrieval phase where they were presented with negative words relevant to social anxiety, and positive words related to social success. The results showed that children with high levels of social anxiety recalled significantly less positive and more negative self-referent words than the low socially anxious group. This suggests that the use of self-referent tasks may be more robust measures of capturing implicit memory biases compared to explicit memory recall tasks that are typically used. However, there is limited evidence that exists on anxiety-related memory biases in youth and further research on this type of cognitive distortion as a possible mechanism underlying worry in adolescents is needed (Muris & Field, 2008).

Historically, research on cognitive biases such as attention, interpretation, and memory, have been investigated in isolation. This means that little is known about how the different cognitive biases work together to maintain psychopathology. The combined cognitive bias hypothesis (Hirsch et al., 2006), proposes that cognitive biases are unlikely to operate as independent and separate processes, but rather, they are likely to influence each other and interact to maintain a given disorder. Importantly, the hypothesis suggests that the combined effects of cognitive biases may have a greater impact on sustaining psychopathology than if individual biases were to work in isolation.

Most research investigating the combined cognitive bias hypothesis has been conducted in adults (Hertel & El-Messidi, 2006; Hertel, Brozovich, Joormann, & Gotlib, 2008; Ellis, Beevers, & Wells, 2011; Everaert, Duyck, & Koster, 2014; Koster, De Raedt, Leyman, & De Lissnyder, 2010; Salemink, Hertel, & Mackintosh, 2010; Tran, Hertel, & Joormann, 2011) with few studies in children and adolescents. Two studies have examined the combined cognitive bias hypothesis in children with social anxiety (Higa & Daleiden, 2008; Vassilopoulos, 2012), whilst two studies have assessed the combined cognitive bias hypothesis in adolescents with varying levels of anxiety and depression (Klein et al., 2017; Orchard & Reynolds, 2018). Klein and colleagues (2017) found that adolescents with high levels of self-reported anxiety and depression showed stronger biases in both attention and interpretation compared to adolescents with low levels of self-reported anxiety and depression. More recently, Orchard and Reynolds (2018) demonstrated that a combination of interpretation bias and self-evaluation bias was a stronger predictor of depression severity in adolescents than individual biases alone. These studies suggest that a combination of cognitive biases may be important in explaining how psychopathology develops in adolescents.

In recent years, there has been growing agreement that cognitive biases should be examined in an integrative manner to better understand the underlying processes of emotionally distorted cognitive functioning (Everaert, Koster, & Derakshan, 2012; Hirsch et al., 2006). As this field is still in its infancy, several questions on how biases interact to maintain anxiety requires further empirical investigation and understanding how these processes develop in adolescents is crucial. Recent studies show that adolescence reflects a period of heightened sensitivity and neuroplasticity in brain development (Fuhrmann et al., 2015; Steinberg, 2014), which suggests that adolescence may be an important stage to investigate the development of worry. Whilst most cognitive models have focused on the role of cognitive biases in the aetiology of anxiety, few have specifically addressed worry. An exception is the cognitive model of pathological worry in adults (Hirsch & Matthews, 2012). As described in Chapter Two, the model proposes that intrusive and worrisome thoughts arise from the interaction between 'bottom-up' processes of cognitive biases and 'top-down' executive control processes. Hirsch and Matthews' model of pathological worry (2012) may provide a useful framework in understanding the cognitive processes that contribute to worry in adolescents. However, this model is yet to be tested in younger populations.

In summary, evidence shows that cognitive biases are associated with the development and maintenance of anxiety in adolescents. However, no studies to date have examined how these cognitive biases operate and contribute to the process of worry in adolescents. Therefore, the aim of the present study was to investigate how cognitive biases are associated with worry in adolescents. Specifically, we examined whether attention bias, interpretation bias, and memory bias are related to levels of worry in adolescents. These three cognitive biases were selected as they are the most common biases featured in information-processing models of anxiety in youth, and are hypothesised to play a role in the development and maintenance of anxiety (Kendall, 1985; Crick & Dodge, 1994; Muris & Field, 2008). A deeper understanding of the cognitive mechanisms associated with worry in adolescents has important implications for identifying the processes to be targeted during treatment and early interventions, and evaluating whether current treatments target the appropriate risk mechanisms. Importantly, investigating how these cognitive biases manifest in healthy adolescents and the interrelationships amongst attention, interpretation and memory biases would provide greater insight into how pathological worry develops in the early stages, with the potential to prevent long-term negative outcomes.

Firstly, we hypothesised that negative interpretations of ambiguous scenarios would be associated with high worry in adolescents, whilst positive interpretations of ambiguous scenarios would be associated with low worry in adolescents. Secondly, we predicted that attention biases towards threatening stimuli would be associated with high worry in adolescents. Thirdly, we hypothesised that negative memory biases would be associated with high worry in adolescents. Finally, in line with the combined cognitive bias hypothesis, we predicted that attention, interpretation, and memory biases would be positively correlated with one another in adolescents. Moreover, having a combination of negative attention bias, negative interpretation bias, and negative memory bias would be strongly associated with high worry in adolescents.

3.2. Method

Participants

Participants were 504 adolescents aged 11 to 14 years old (*M* = 13.37, *SD* = .75), attending secondary schools in the South England area. The sample consisted of ten cohorts, from nine different high schools, including private and comprehensive schools. The majority of cohorts were in year eight (6:10), with the addition of two cohorts in year seven and two cohorts in year nine. The majority of cohorts were from same-sex schools (6:10) and our final sample comprised of 56% females. Demographic information was collected from parents, and of the participants, 75% were White or European, 6% were from mixed background, 4% were South Asian, 2% were African or Caribbean, 2% were East Asian, 0.6% were from Arab or Middle Eastern decent, whilst 11% chose not to respond. Parents who responded to questions about education indicated that the highest level of education attained was a Bachelor's degree (24%), some college (14%), Master's degree (13%), vocational training (8%), high school (7%), or a Doctoral degree (2%). Participants eligible to take part in the study were adolescents in secondary school aged between 11 and 17, being fluent in English, and having a parent and adolescent able to give written informed consent or assent. Participants were excluded from the study if they were currently suffering from a psychological disorder and any neurological impairment or learning disability that would make them unable to take part. The inclusion and exclusion criteria was determined by parental self-report on the demographics questionnaire.

Design

The data was drawn from the CogBias Longitudinal study (see Booth, Songco et al., 2017 for study protocol), which aims to investigate the cognitive and genetic markers of resilience and emotional vulnerability in adolescents. The study followed the cognitive and emotional development of over 500 adolescents at three different time points, at approximately the age of 12, 14, and 16. At each time point, adolescents completed cognitive tasks that assessed cognitive biases, executive functions, and action-tendencies as well as a range of subjective measures including anxiety, depression, worry, rumination, resilience, impulsivity, life experiences, eating behaviours, and risk-taking. In addition, saliva samples were collected from each participant at time point 1 to assess genetic variation. Height and weight measures were also collected from participants at each time point to assess BMI. The sample size was based on typical effect sizes in previous cognitive bias and action tendencies research (Hallion & Ruscio, 2011) and a sample of at least 500 adolescents was selected to ensure a medium degree of statistical power. This research design measured a wide range of cognitive and subjective factors during an important developmental period in adolescents, which could provide insight into the risk and protective factors that may be key targets for interventions designed to improve psychological wellbeing and resilience. The data presented in this chapter was drawn from time point 1 (M = 13.37, SD = .75).

Recruitment

Participants were recruited through secondary schools, by writing emails to head teachers describing the aims of the CogBias Longitudinal study. Fifty-one schools were contacted in the South of England and 30% of schools were initially interested. The final sample (N = 504) included 20% of the schools contacted. Once the school had agreed to take part in the study, teachers distributed an information pack to parents containing a detailed parent information sheet, an adolescent information sheet, a parent consent form, and demographic questionnaire, either electronically or through paper form. Participants were recruited using an opt-in method and we obtained parental consent for 530 adolescents to take part in the CogBias Longitudinal study. On the days of data collection, 26 adolescents were absent from schools and were not subsequently included in the study because of time constraints of arranging testing sessions. Participation in the study was voluntary and adolescents were compensated by means of a £10 Amazon voucher at each of the three time points. In addition, schools were offered enrichment activities such as talks to students and organising work experience opportunities in our research lab at the University of Oxford.

Procedure

The testing sessions were organised by each individual school cohort and were conducted in schools during normal lessons, except for three cohorts who came to the Department of Experimental Psychology, University of Oxford (*n* = 116). Testing was completed in computer labs in group conditions, ranging in size from 13 to 54 students (*M* = 22, *SD* = 10.78) with at least two researchers present. At the start of each session, researchers distributed assent forms and a unique participant number to ensure confidentiality and anonymity of responses. The testing session lasted two hours where participants completed cognitive tasks and self-report questionnaires individually under exam conditions, with a short break after one hour. Height and weight was measured during the testing session individually with a researcher in a private room. In addition, saliva samples were collected at the end of the session using *DNA Genotek Oragene OG-500* collection kits.

Measures

In this chapter, we analyse only data that are relevant for the current study's research questions. Brief descriptions of these measures are presented below, however, a complete description of the sample, methods, and design of the larger, longitudinal study can be found here (Booth, Songco et al., 2017).

Self-report measures

Demographic questionnaire. Parent self-report on a demographic questionnaire assessed information such as adolescent's age, gender, ethnicity, household size, parent's education and occupation. Information pertinent to socio-economic status (SES) included household size, mother and father's occupation, and mother and father's level of education. Whilst these factors have been traditionally used as SES indices (Buchmann, 2002; Hauser, 1994; Yang & Gustafsson, 2004), parental education has been shown to be a reliable proxy of SES as it affects income and occupation, and family income affects opportunities for education (Hoff, Lauresen, & Tardif, 2002). In the present study, we created an index of SES by calculating the mean score of mother and father's highest level of education attained. In addition, to account for differences at the school level in our sample, we created a variable (i.e. school) based on the number of cohorts in the study (i.e. ten cohorts). This variable captures the different schools, year levels, time of year that the sessions were conducted, and the various time lags amongst the testing sessions in schools. In our analyses, we control for gender, school, and SES.

Worry. The Penn State Worry Questionnaire for Children (PSWQ-C; Chorpita, Tracey, Brown, Collica, & Barlow, 1997) is a 14 item self-report measure used to assess the tendency to worry in children aged 6 to 18 years old (see Appendix B). Examples of items include "My worries really bother me" and "I know I shouldn't worry, but I just can't help it." Each item was rated on a 4-point Likert scale (0 = Never true to 3 = Always true) and a total score was calculated by summing the items. Higher scores on the PSWQ-C indicate more frequent and uncontrollable worries. In adolescent samples, the PSWQ-C has excellent internal consistency, good convergent and discriminant validity, and test-retest reliability in clinical and non-clinical samples (Chorpita et al., 1997; Pestle, Chorpita, & Schiffman, 2008). The internal consistency on the PSWQ-C for the current study was high (α = .92), which is consistent with the reliability of previous research.

Cognitive tasks

Attention bias. A pictorial Dot-probe task (MacLeod et al., 1986) with angry faces (threat bias), happy faces (positive bias), and pain faces (empathy bias) was used to assess attention bias. The task comprised of three blocks corresponding to each of these categories. Within each emotion block, 56 trials presented an emotional face paired with a matched neutral face for 500ms, followed by a probe for 3000ms either behind the emotional face (congruent trials) or behind the neutral face (incongruent trials). See Appendix C for an example trial sequence. Therefore attention bias for emotion could be inferred if reaction time (RT) was faster on congruent compared to incongruent trials. The faces were chosen from the STOIC faces database (Roy et al., 2007), which is a validated set of ten actors expressing six basic emotions. We chose seven actors (four male: three female) and four emotions (neutral, anger, happiness, pain) to make up our task of 168 trials, with each actor shown eight times in each block. The faces were presented in greyscale with no hair or jawline showing on a grey background. Pictures were 230 x 230 pixels in size and presented approximately ten degrees visual angle apart. Probes were the letters ‘Z’ and ‘M’ corresponding to the correct response, which were presented equally on the left or right, to increase task difficulty and encourage attentional engagement. The inter-trial interval (ITI) was 500ms, followed by a fixation cross that was presented for 500ms to signal the start of a new trial. Participants were instructed to focus on the fixation cross and ignore the faces, but respond to the probe as fast and accurately as they could. An error message was shown if participants made an incorrect response or if no response was made within 3000ms. Block order was counterbalanced across participants and a rest period of 30000ms with a timer was displayed between blocks. Participants also completed a practice block with eight trials depicting only the probe and 16 trials with neutral-neutral face pairings, which were not analysed.

Visual analogue scales (VAS) were presented immediately before and after the task to assess mood. Participants were asked to rate how happy they felt and how sad they felt at that moment using a 10-point sliding scale. After the data was prepared, we calculated each participants mean RT for each emotional condition and trial type. That is, we created six variables (angry congruent, angry incongruent, pain congruent, pain incongruent, happy congruent, and happy incongruent) and calculated a bias index score for each emotional condition separately (angry, pain, and happy). Bias indices were calculated as the difference in RT between congruent and incongruent trials (high numbers reflected attentional orienting). Robust split-half reliabilities (Parsons, 2017) for the bias indices were low; Angry bias = .10 (Spearman-Brown corrected .17), Happy bias = .05 (Spearman-Brown corrected .09), and Pain bias = -.05 (Spearman-Brown corrected -.12).

Interpretation bias. The Adolescent Interpretation and Belief Questionnaire (AIBQ; Miers, Blöte, Bögels, & Westenberg, 2008) was used to assess interpretation bias to hypothetical social and non-social scenarios. Participants read ten ambiguous scenarios, then were presented with three thoughts that could arise in response to each scenario (see Appendix D). Participants then rated how much each thought would be likely to pop into their head using a 5-point Likert scale (1 = Does not pop in my mind, 3 = Might pop in my mind, 5 = Definitely pops in my mind). The interpretations for each scenario were either neutral, positive or negative. Interpretations for each situation were presented in a fixed random order. The following four outcome variables were created; Positive Interpretation

(Social) as the sum of the ratings on the positive social interpretations divided by the five social situations; Negative Interpretation (Social) as the sum of the ratings on the negative social interpretations divided by the five social situations; Positive Interpretation (Non-Social) as the sum of the ratings on the positive non-social interpretations divided by the five non-social situations; and Negative Interpretation (Non-Social) as the sum of the ratings on the negative non-social interpretations divided by the five non-social situations. Scores ranged from 1 (no bias) to 5 (strong bias) for each of the four outcome variables. The internal consistency for the subscales of the AIBQ were; Positive Interpretation (Social) $\alpha = .55$, Negative Interpretation (Social) $\alpha = .78$, Positive Interpretation (Non-social) $\alpha = .43$, and Negative Interpretation (Non-social) $\alpha = .57$, which is in line with previous literature. This measure has shown good reliability and validity in studies across adolescents and emerging adulthood (Kingsbury & Coplan, 2016; Miers et al., 2008; Miers, Blote, de Rooij, Bokhorst, & Westenberg, 2013).

Memory bias. The Self-referential Encoding Task (SRET; Hammen & Zupan, 1984) was used to assess memory bias for self-referential words. The task comprised of three phases; an encoding phase, a distraction phase, and an incidental free recall phase. In the encoding phase, self-referent adjectives were displayed on the screen for 200ms, followed by the caption “Describes me?” at which point participants could respond with either yes or no using the “Y” and “N” keys. A new word was presented after a valid response was made. The word list comprised of 22 positive (e.g. “attractive”, “funny”) and 22 negative (e.g. “unhappy”, “boring”) self-referent adjectives that had been validated for use in an adolescent sample and had been matched on word length and recognisability (Hammen & Zupan, 1984). See Appendix E for word stimuli. In the distraction phase, participants were instructed to solve three simple mathematics equations by typing their response into a short answer box. In the incidental free recall phase, participants were instructed to type as many words as they could remember from the “Describes me” task, regardless of whether they endorsed the word, into a long answer box. They were given three minutes for recall, at which point the task ended. In line with previous studies, negative memory bias was computed as the total number of negative words that are endorsed and recalled, and positive memory bias as the total number of positive words endorsed and recalled (Asarnow, Thompson, Joorman, & Gotlib, 2014).

Data Analysis Plan

Hierarchical multiple regression

Three separate hierarchical multiple regressions for each of the cognitive biases (attention, interpretation, and memory) were performed using the tendency to worry (PSWQ-C) as the outcome variable. Demographic variables of gender, school, and SES were entered in the first step of the hierarchical multiple regressions in order to control for the variance accounted for by these three factors. To investigate the relationship between attention bias and worry, the three attention bias indices (Dot-probe) were included in the second step of the hierarchical multiple regression using the enter selection method. Similarly, to examine the relationship between interpretation bias and worry, the four interpretation bias outcome variables (AIBQ) were added in the second step of the analysis using the enter selection method. Whilst, in a hierarchical multiple regression assessing the relationship between memory bias and worry, negative memory bias and positive memory bias (SRET) were added in the second step of the analysis using the enter selection method. For the three hierarchical regression models, preliminary analyses were conducted to ensure that there were no violations of the assumptions of normality, linearity, multi-collinearity, and homoscedasticity.

A post-hoc power analysis was conducted using the software package G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). The sample size of 504 was used for the statistical power analyses and a six predictor variable equation was used as a baseline for the regression model with the attention bias variables, seven predictors for the regression model with the interpretation bias variables, and five predictors for the regression model with the memory bias variables. The recommended effect sizes used for this analyses were as follows: small (f^2 = 0.02), medium (f^2 = 0.15), and large (f^2 = 0.35) (Cohen 1988). The alpha level used for this analysis was p <.05. The post-hoc analyses revealed the statistical power for this study was 1.00 for detecting an effect, which is considered to be large using Cohen's criteria. Thus, there was more than adequate power for this study to detect a moderate to large effect.

Principle components analysis

A Principle Components Analysis (PCA) with oblimin rotation was performed to reduce the nine cognitive bias variables produced by the Dot-probe (i.e. Angry bias, Pain bias, and Happy bias indices), the AIBQ (i.e. Negative Interpretation (Social), Negative Interpretation (Non-social), Positive Interpretation (Social), and Positive Interpretation (Non-social) subscales), and the SRET (Negative memory bias and Positive memory bias) to create composite bias scores, which we refer to as *poly-bias scores.* This novel method to create poly-bias scores allows examination of the interrelationships among the different cognitive biases (Orchard & Reynolds, 2017, unpublished manuscript).

In the first step of the PCA, correlations of all bivariate relationships were examined. To perform the PCA, an oblimin rotation was used as the cognitive bias literature suggests that the underlying factors are related and oblimin rotation is more suitable for correlated factors than other approaches. Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity were analysed to ensure the requirements for PCA were met. The number of components were determined using Keiser's criterion (eigenvalues > 1.0) and only components with factor loadings of .30 or above were retained.

Based on the outcome of the PCA, we calculated factor scores by summing the weighted betas of the relevant items to create poly-bias scores. For example, to compute the factor score for a given case for a given factor, the case's standardized score on each variable is multiplied by the corresponding weighted beta of the variable for the given factor, and sums these products. We selected this method of calculating factor scores as it reflects an optimally weighted sum of the items as each item's contribution to the factor score depends on how strongly it relates to the factor. Poly-bias scores were then used to examine whether multiple cognitive biases were associated with outcomes of worry in adolescents. Hierarchical multiple regression was conducted with the poly-bias scores as the independent variables and worry as the outcome variable (PSWQ-C). Gender, school, and SES were entered in the first step of the hierarchical multiple regression in order to control for the variance accounted for by these factors and potentially confounding effects. The poly-bias scores were then included in the second step of the hierarchical multiple regression analysis using the enter method selection.

Missing data

There was no missing data on the PSWQ-C (N = 504). However, due to technical fault, no data was saved for seven participants on the AIBQ (N = 497). In addition, no data was saved for five participants on the Dot-probe task due to technical issues and a further four participants were excluded for performing at less than 70% accuracy (N = 495). Error trials were excluded from the dot-probe analysis (8% of trials), as well as trials with RT's faster than 200ms or slower than 3000ms (<1% of trials) to remove trials reflecting pre-emptive responses or delayed responses, respectively. We also removed response latencies that were three *SD's* from each participant's mean RT for each emotional condition and congruency type (2% of trials). Furthermore, no data was saved for one participant on the SRET due to a technical fault (N = 503). In addition, SES data was missing for 19 participants. The analyses were performed excluding participants with missing data.

3.3. Results

Descriptive Statistics at Time Point 1

Descriptive statistics of the sample are presented in Table 3.1. The mean level of worry for the current sample (M = 21.74, SD = 9.11) was slightly higher than the mean levels of worry on the PSWQ-C in community samples of adolescents (*M range* = 15.29 to 19.24), however still below clinical cut off scores (Chorpita et al., 1997; Dugas, Laugesen, & Bukowski, 2012; Pestle et al., 2008). In addition, females reported significantly higher levels of worry (M = 23.28, SD = 9.66) compared with males (M = 19.84, SD = 8.02); $t(502) = -4.28$, $p < .001$; d = 0.39), which is consistent with the previous literature. There were no significant correlations observed between age and worry, as well as SES and worry (*ps* >.05). A one-way ANOVA indicated a significant difference in mean levels of worry amongst the school cohorts ($F(9, 494) = 4.07$, $p < .001$, $\eta^2 = .69$). Furthermore, a one way ANOVA revealed a significant difference between school cohorts and SES ($F(9, 475) = 13.29$, $p < .001$, $\eta^2 = .20$). Therefore, in subsequent analyses, we controlled for gender, school, and SES in order to control for the variance in worry accounted for by these factors. Table 3.2. presents the correlations amongst all bivariate relationships between worry, attention bias, interpretation bias, and memory bias, with associations all in the expected direction.

Table 3.1

Sample Characteristics for the CogBias Longitudinal Study (Time Point 1) by Cohort

Variable	Total	1	2	3	4	5	6	7	8	9	10
N	504	15	30	62	47	13	34	119	104	54	26
Mean Age (SD)	13.37 (.37)	12.56 (.41)	11.75 (.27)	13.39 (.28)	13.43 (.29)	12.20 (.37)	12.76 (.28)	14.02 (.38)	13.08 (.33)	14.33 (.26)	13.20 (.31)
Year group	7 - 9	7	7	8	8	8	8	9	8	9	8
Gender (% females)	55	40	50	100	100	100	47	0	100	0	58
Mean Worry (SD)	21.74 (9.11)	17.27 (6.65)	18.03 (8.11)	22.66 (9.53)	25.62 (10.75)	23.62 (7.57)	18.32 (7.36)	20.77 (8.04)	23.15 (9.60)	19.72 (8.23)	25.81 (9.63)
Height cm (SD)	162.22	158.81 (7.79)	152.18 (7.59)	159.86 (6.18)	162.49 (7.21)	155.46 (7.06)	158.03 (7.27)	168.34 (8.71)	158.75 (6.32)	168.46 (8.29)	159.92 (8.44)
Weight kg (SD)	52.74 (11.42)	44.21 (6.39)	44.02 (10.33)	52.66 (10.32)	57.45 (15.31)	47.15 (8.26)	52.91 (11.59)	55.94 (11.10)	50.70 (9.97)	55.10 (10.44)	51.39 (10.35)
BMI (SD)	19.90 (3.27)	17.48 (1.94)	18.83 (3.33)	20.55 (3.47)	21.41 (4.24)	19.49 (3.11)	21.12 (4.13)	19.62 (2.78)	20.01 (3.16)	19.28 (2.62)	20.02 (3.39)

Note. Column numbers indicate cohort number; Worry = Penn State Worry Questionniare - Child version (PSWQ-C)

Table 3.2

Correlations of Worry with Cognitive Bias Variables

Variable	1	2	3	4	5	6	7	8	9
1. Worry									
2. Angry Bias	.02								
3. Pain Bias	-.07	.09*							
4. Happy Bias	.05	.05	-.04						
5. Negative Interpretations_social	.49**	.07	-.07	-.04					
6. Negative Interpretations_non-social	.33**	-.00	-.04	-.03	.51**				
7. Positive Interpretations_social	-.28**	.02	-.04	-.01	-.25**	.04			
8. Positive Interpretations_non-social	-.21**	-.00	-.05	-.02	-.12**	-.15**	.39**		
9. Negative Memory Bias	.48**	.04	-.11*	.01	.42**	.23**	-.30**	-.24**	
10. Positive Memory Bias	-.18**	-.06	.05	.05	-.22**	-.15**	.28**	.20**	-.26**

Note. *p < .05 **p <. 01

Hierarchical Multiple Regression

Attention bias analysis

The results of the hierarchical multiple regression of attention bias on outcomes of worry, controlling for gender, school, and SES are presented in Table 3.3. The analysis revealed no significant relationship between worry and selective attention towards angry, pain or happy faces. In the first step of the hierarchical multiple regression, gender, school, and SES made a significant contribution to the variance in worry scores ($F(3, 473) = 7.65$, $p <.001$) and explained 5% of the variance. After entry of the attention bias variables at the second step of the analysis, the model was not significant ($F(3, 470) = 1.03$, $p =.377$).

Table 3.3

Summary of Hierarchical Multiple Regression for Attention Bias (Dot-probe) and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.05**				
Gender		3.81	.87	.21***	4.41
School		.44	.18	.12*	2.50
SES		-.30	.34	-.04	-.87
Step 2	.01				
Gender		3.73	.87	.20***	4.28
School		.42	.18	.11*	2.40
SES		-.33	.34	-.04	-.97
Angry Bias		.01	.01	.03	.66
Pain Bias		-.01	.01	-.05	-1.14
Happy Bias		.01	.01	.05	1.19

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

Interpretation bias analysis

The results of the hierarchical multiple regression of interpretation bias on outcomes of worry, controlling for gender, school, and SES are presented in Table 3.4. In the first step, gender, school, and SES made a significant contribution to the variance in worry scores ($F(3, 476) = 7.60$, $p < .001$) and explained 5% of the variance. At the second step, the total variance explained by the model was 31% ($F(7, 472) = 29.83$, $p < .001$). The interpretation bias variables explained an additional 26% of the variance in worry, after controlling for gender, school, and SES ($\Delta R^2 = .26$, $F(4, 472) = 44.41$, $p < .001$, $f^2 = 0.38$). Negative interpretations of social and non-social scenarios, as well as positive interpretations of social and non-social scenarios made a significant contribution to the variance of worry. The strongest predictor of worry on the AIBQ was negative interpretation of social scenarios (β = .35), followed by positive interpretation of social scenarios (β = -.15), negative interpretation of non-social scenarios (β = .14) then positive interpretation of non-social scenarios (β = -.10). We also tested for a gender x interpretation bias interaction, but there were no significant interactions of gender differences between worry and interpretation bias ($F(4, 468) = 1.29$, $p = .275$).

Table 3.4

Summary of Hierarchical Multiple Regression for Interpretation Bias (AIBQ) and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.05***				
Gender		3.84	.87	.21***	4.44
School		.43	.18	.11*	2.43
SES		-.27	.34	-.04	-.81
Step 2	.26***				
Gender		1.84	.76	.10*	2.42
School		.27	.15	.07	1.78
SES		-.02	.30	.00	-.05
Negative Interpretations_social		3.68	.49	.35***	7.46
Negative Interpretations_non-social		1.81	.60	.14*	3.00
Positive Interpretations_social		-2.22	.65	-.15*	-3.40
Positive Interpretations_non-social		-1.38	.62	-.10*	-2.22

Note. PSWQ-C = Penn State Worry Questionnaire - Child version; AIBQ = Adolescent Interpretations and Beliefs Questionnaire

[a] *p < .05 ** p< .01 ***p < .001

Memory bias analysis

The results of the hierarchical multiple regression of memory bias on outcomes of worry, controlling for gender, school, and SES are presented in Table 3.5. In the first step, the demographic variables of gender, school, and SES made a significant contribution to the variance in worry ($F(3, 480) = 7.72$, $p < .001$) and explained 5% of the variance. In the second step, the total variance explained by the model was 25% ($F(5, 478) = 32.35$, $p < .001$). The memory bias variables explained an additional 21% of the variance in worry, after controlling for gender, school, and SES ($\Delta R^2 = .21$, $F(2, 478) = 66.13$, $p < .001$, $f^2 = 0.25$). Negative memory bias was the strongest predictor of worry ($\beta = .45$), whilst positive memory bias did not make a significant contribution to worry. We also tested for a gender x memory bias interaction, however there were no significant interaction effects of gender on worry and memory bias ($F(2, 476) = .60$, $p = .549$).

Table 3.5

Summary of Hierarchical Multiple Regression for Memory Bias (SRET) and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.05***				
Gender		3.86	.86	.21***	4.48
School		.42	.17	.11*	2.40
SES		-.30	.34	-.04	-.90
Step 2	.21***				
Gender		1.39	.80	.08	1.73
School		.35	.16	.09*	2.22
SES		-.37	.30	-.05	-1.22
Negative Memory Bias		1.80	0.17	.45***	10.52
Positive Memory Bias		-.21	.14	-.06	-1.53

Note. PSWQ-C = Penn State Worry Questionnaire - Child version; SRET = Self-Referential Encoding Task

[a] *p < .05 ** p< .01 ***p < .001

Principle Components Analysis

Correlations between the cognitive bias variables and worry are presented in Table 3.2. The results showed small to moderate associations between interpretation bias variables and memory bias variables. However, attention bias was not significantly correlated with either interpretation bias or memory bias (*ps* > .05), except for a small negative association between an attention bias towards pain and negative memory bias (r = -.11). Furthermore, the results indicated that worry was significantly associated with interpretation bias and memory bias. However, there were no significant associations between worry and attention bias (*ps* > .05). Overall, the correlation table showed that attention bias was not significantly correlated with the other bias variables or worry scores.

The results of the PCA are presented in Table 3.6. The Kaiser-Meyer-Olkin measure of Sampling Adequacy (KMO = .605) and Bartlett's test of sphericity ($\chi^2(36) = 525.70$, $p < .001$) indicated that the sample size and the data were adequate for conducting PCA. The analysis yielded four factors with eigenvalues greater than one and explained 63% of the total variance. Factor one (eigenvalue = 2.27) accounted for 25% of the variance, factor two (eigenvalue = 1.27) accounted for a further 14% of the variance, whilst factors three and four (eigenvalues = 1.08 and 1.05 respectively) each accounted for 12% of the total variance.

The pattern of factor loadings revealed four factors. Factor one was interpreted as *Positive Bias* and comprised of high factor loadings of the variables: positive interpretations of social scenarios, positive interpretations of non-social scenarios, and positive memory bias. Factor two was identified as *Negative Bias* due to moderate to high factor loadings of the variables: negative interpretations of social scenarios, negative interpretations of non-social scenarios, and negative memory bias. Factor three was related to an *Attention Bias to Threat* and included high factor loadings of the variables: angry bias and pain bias. Finally, factor four was interpreted as *Attention Bias* towards emotional stimuli due to factor loadings of the variables: angry bias, pain bias, and happy bias. The variable negative memory bias loaded on both factor one and factor two, however conceptually it was more meaningful to include in factor two (Negative Bias). Based on the outcome of the PCA, we calculated factor scores by summing the weighted betas of the relevant items to create four poly-bias scores (Positive Bias, Negative Bias, Attention Bias to Threat, and Attention Bias).

In addition to the above mentioned PCA, a separate PCA was conducted to examine whether exclusion of the attention bias variables (angry bias, pain bias, and happy bias) revealed a consistent factor structure (see Appendix F). This analysis was performed as the correlation matrix (Table 3.2) indicated that attention bias was not correlated with interpretation or memory bias, and previous research suggests that items that do not correlate with other items should be initially excluded in a PCA. However, the results yielded a consistent factor structure in both analyses, when the attention bias variables were included and excluded, indicating that the interpretation bias and memory bias variables behaved the same way in every case. All subsequent analysis were conducted including and excluding the attention bias variables, and no differences were found. Therefore, the decision was made to include the attention bias variables in the PCA as this was the first exploratory analysis to examine the interrelationship among attention, interpretation, and memory biases in adolescents. We were interested in how multiple cognitive biases loaded onto the different latent components in order to assess the combined cognitive bias hypothesis.

Table 3.6

Factor Loadings for Principle Components Analysis on Cognitive Bias Variables

Item	Positive Bias	Negative Bias	Attention Bias to Threat	Attention Bias
Positive Interpretations_social	-.85			
Positive Interpretations_non-social	-.73			
Positive Memory Bias	-.50			
Negative Interpretations_non-social		.86		
Negative Interpretations_social		.80		
Negative Memory Bias	.44	.44		
Pain Bias			.77	-.32
Angry Bias			.70	.41
Happy Bias				.87

Note. Principle Components Analysis using Oblimin rotation; Factor loadings < .30 are omtted

Hierarchical Multiple Regression with Poly-bias Scores

The results of the hierarchical multiple regression with the poly-bias scores (Positive Bias, Negative Bias, Attention Bias to Threat, and Attention Bias) and outcome of worry (PSWQ-C) are presented in Table 3.7. In the first step of the model, gender, school, and SES made a significant contribution to the variance in worry ($F(3, 471) = 7.56$, $p <.001$) and explained 5% of the variance. At the second step of the analysis, after entry of the poly-bias scores, the total variance explained by the model was 35% ($F(7, 467) = 35.19$, $p <.001$, $f^2 = 0.46$). A Negative Bias score (β = .48) made the strongest contribution to the variance of worry followed by a Positive Bias score (β = .19). Attention Bias and Attention Bias to Threat was not significantly associated with worry. We also examined whether there was a gender x Negative Bias or gender x Positive Bias interaction, but there were no significant interactions of gender differences between worry and the poly-bias scores ($F(4, 463) = 0.27$, $p =.899$).

Table 3.7

Summary of Hierarchical Multiple Regression for Poly-bias Scores and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.05***				
Gender		3.80	.87	.21***	4.38
School		.44	.18	.12*	2.48
SES		-.30	.34	-.04	-.87
Step 2	.30***				
Gender		1.48	.75	.08*	1.98
School		.32	.15	.09*	2.19
SES		.02	.29	.00	.07
Negative Bias		4.52	.37	.48***	12.11
Positive Bias		1.95	.41	.19***	4.72
Attention Bias to Threat		-.25	.36	-.03	-.69
Attention Bias		.60	.36	.06	1.65

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

3.4. Discussion

In the present study, the hypothesis that negative interpretations of ambiguous scenarios would be associated with high worry in adolescents, and positive interpretations of ambiguous scenarios would be associated with low worry in adolescents, was supported. In addition, we found evidence to suggest that negative memory bias was associated with high worry in adolescents. However, contrary to our prediction, attention biases towards threatening stimuli was not associated with high worry in adolescents. Moreover, in line with the combined cognitive bias hypothesis, we found that interpretation and memory biases were moderately correlated with one another in adolescents. We also demonstrated that a combination of multiple cognitive biases, which we termed poly-bias scores, were associated with worry in adolescents. These findings extend the current literature on the association between cognitive biases and adolescent worry.

The results of the present study indicate that adolescents with negative interpretations of ambiguous scenarios, in both social and non-social contexts, showed higher levels of worry. In contrast, adolescents with more positive interpretations of ambiguous social and non-social scenarios, showed low levels of worry. This suggests that negative interpretations of ambiguous situations are related to worrisome thoughts, perhaps due to the uncertainty and unpredictability of the future. Conversely, having a positive interpretation towards ambiguity may act as a protective factor against high worry in adolescents. These findings are consistent with previous studies, which have shown that anxious adolescents tend to interpret ambiguous information as more negative and threatening compared to non-anxious adolescents (Castillo & Leandro, 2010; Stuijfzand et al., 2017). Furthermore, the findings extend the current literature to adolescents, with only two prior studies examining this relationship between worry and cognitive biases in children (Suarez & Bell-Dolan, 2001; Suarez-Morales & Bell, 2006). Overall, the results indicate that interpretation biases are cognitive mechanisms that play a role in adolescent worry.

The present study also found that negative memory bias was associated with high worry in adolescents, which suggests that negative information may be more salient and readily recalled in adolescents with high levels of worry. This is consistent with studies that have used a self-referent encoding task to demonstrate a negative memory bias in anxious and depressed youth (Goldstein, Hayden, & Klein, 2015; Vassilopoulous, 2012). Previous research has typically used explicit memory recall tasks, which have shown mixed results for threat-related memory biases in anxious youth (Mitte, 2008). Perhaps the use of self-referent encoding tasks, taps into cognitive processes linked to negative mental representations that anxious youth have of themselves, which may be more meaningful to threat-related memory biases. However, there are few studies that have examined the association between memory biases and worry in youth and further research is needed to replicate and validate the current findings. The present study demonstrates that worry is associated with negative memory and negative interpretation biases. Future research using longitudinal paradigms would provide further insights into the causal relationship between worry and negative cognitive biases, and a better understanding of the cognitive mechanisms that contribute to adolescent worry.

In addition, the current results indicate that attention bias towards threat was not associated with high worry in adolescents. This is surprising, given that previous studies have shown that anxious youth display a biased attention towards threat-related stimuli, relative to positive or neutral stimuli, compared to their non-anxious peers. However, the literature pertaining to an attention bias towards threat in youth is mixed (Bar-Haim et al., 2007; Dudeney et al., 2015; Puliafico & Kendall, 2006). It has been suggested that inconsistent results may be due to age related effects and methodological variations in tasks and parameters used in attention bias research. A recent meta-analysis found that differences in processing threat amongst anxious and non-anxious youth was strongly moderated by age (Dudeney et al., 2015), with a threat bias more common in younger anxious children (Dodd et al., 2015; Shechner et al., 2013, 2017). Thus, attentional processes may emerge at various stages of childhood and adolescent development and further research examining attention biases in adolescent populations would help to disentangle age-related differences in attention. Together, these findings suggest that worry in adolescents may be more related to the interpretation of ambiguity and memory recall, rather than the initial capture of attention towards threatening or negative information.

This is further supported by the data investigating the combined cognitive bias hypothesis in our sample of adolescents. The principle components analysis revealed that interpretation bias and memory bias in adolescents are closely interrelated cognitive processes, and in combination, are associated with adolescent worry. The findings suggest that a Negative Bias poly-bias score, comprised of a combination of negative interpretation and negative memory bias, had the strongest association with high worry in adolescents. Whilst, a Positive Bias poly-bias score, which included a mixture of positive interpretation biases and positive memory bias, was associated with low worry in adolescents. Interestingly, an Attention Bias and Attention Bias to Threat poly-bias score, was not associated with worry in adolescents. Considering the mixed findings of attention bias towards threat in youth and the poor split half reliability issues with the Dot-probe task in our sample of adolescents, the results need to be interpreted with caution and further replication is warranted.

This novel approach of examining cognitive biases provides support for the combined cognitive bias hypothesis in adolescents, and a better understanding of how these cognitive processes may be intercorrelated during this important developmental period. The present findings of the interrelationship between interpretation and memory biases are consistent with recent studies examining the combined cognitive bias hypothesis in adults (Hertel & El-Messidi, 2006; Hertel et al., 2008; Salemink et al., 2010; Tran et al., 2011), which demonstrate that interpretation biases influence memory as individuals tend to recall information based on their biased interpretation of ambiguous scenarios. Moreover, the results are in line with cognitive models of anxiety in youth, which suggest that interpretation and memory biases occur at the later stages of information-processing, after initial attention is captured and encoded in the cognitive system, and are perhaps cognitive processes that are interlinked (Crick & Dodge, 1994; Daleiden & Vasey, 1997; Muris & Field, 2008). Whilst research in the field is encouraging, experimental and longitudinal studies are needed to investigate the causal relationship between attention, interpretation, and memory biases, and examine how these cognitive biases develop over time.

The present study has a number of strengths and limitations. One limitation to our study is that it is cross-sectional in design, which limits the ability to draw conclusions about causality and the direction of effects between worry and interpretation and memory biases.

Future research using experimental and longitudinal designs would provide useful insight into the causal mechanisms that contribute to worry in adolescents, and how these cognitive processes develop and interact to maintain pathological worry over time. Secondly, the findings of the current study are confined to healthy adolescents and may not be generalisable to clinical populations or adolescents with elevated or subclinical levels of pathological worry or anxiety. Nevertheless, examining the role of cognitive biases in healthy adolescent samples provides valuable insight into the early risk and resilience factors associated with worry, which may be important cognitive pathways to the development of anxiety.

Another limitation in the present study that may contribute to the inconsistent findings, is the low split half reliability of the Dot-probe task in our sample of adolescents. It is possible that the Dot-probe task used in the present study was not reliable enough to provide a stable measure of attention bias. The Dot-probe task was selected as it is one of the most commonly used measures of selective attentional processing. The task parameters in the present study, such as presentation time (i.e. 500ms) and pictorial stimuli to reflect threat, empathy, and happy bias (i.e. angry, pain, and happy faces), were based on paradigms typically used in previous youth and adult literature (Dudeney et al., 2015). However, using different task parameters in the Dot-probe paradigm such as longer stimulus presentation time or linguistic (i.e. words) rather than pictorial stimuli may have influenced the results, and reflects larger methodological issues with the Dot-probe task in attention bias research.

The lack of standardisation of the Dot-probe task across studies that use various task parameters such as length of presentation time, pictorial or linguistic stimuli, different calculation of bias indices, and various comparison groups has yielded mixed results in child, adolescent and adult populations (Dudeney et al., 2015, Kruijt et al., 2016; Parsons et al., 2018). A recent meta-analysis showed that evidence of an attention bias in anxious youth was stronger in studies that used linguistic over pictorial stimuli (Dudeney et al., 2015). In addition, an attention bias in anxious compared to non-anxious youth only emerged in studies using a Dot-probe task with longer stimulus presentation times (>500ms). It has been suggested that perhaps youth may need additional time to process information compared to adults when completing the task, which may reflect differences in cognitive development. Furthermore, the pictorial faces selected in the present study were adult actors and perhaps using child or adolescent faces may have been more relevant to younger populations.

Future research with the Dot-probe task in adolescence should consider the type of stimuli, longer presentation times (i.e. 1000ms or 1250ms), and age-appropriate faces when using the task in attention bias research. The Dot-probe task used in the present study did not yield significant findings in our sample of adolescents, however including different task parameters may have changed the results. Therefore, the attention bias findings in the present study need to be interpreted with caution and further replication, using other paradigms to assess attention bias such as the visual search task, the stroop task, emotional cueing task or eye tracking, is needed to examine the role of attention bias in adolescent worry.

To the best of our knowledge, this was the first study to investigate attention, interpretation, and memory biases simultaneously in adolescents and in relation to outcomes of worry. This extends the current literature on the cognitive biases associated with worry, which may be important cognitive pathways to the development of pathological worry and anxiety in adolescents. In addition, the findings offer preliminary support for the combined cognitive bias hypothesis in adolescents and provides a deeper insight into the cognitive risk and protective mechanisms that are associated with varying levels of adolescent worry.

The present study used a novel approach to create a composite score of cognitive biases, termed poly-bias scores, in order to test the combined cognitive bias hypothesis. This novel method has strengths that make a valuable contribution to the literature and extends our understanding of how cognitive biases may relate to one another and work together during adolescence. One advantage to using the poly-bias approach when investigating the combined cognitive bias hypothesis is that it may help unravel the complex interrelationships between cognitive biases, and facilitate the examination of certain aspects of the theory that remain unanswered. For instance, future studies could use poly-bias scores to assess whether a composite score (i.e. Negative Bias or Positive Bias) is able to predict more variance in adolescent worry than individual cognitive biases in isolation. Importantly, this has the potential to inform future research and early interventions on the cognitive mechanisms underlying adolescent worry and whether these processes should be measured or targeted in treatments in combination.

However, one limitation to using a poly-bias approach is that composite scores can result in over-reduction or loss of information, and it may be that individual biases have a stronger or more meaningful effect on outcome measures. For instance, examining the associations between interpretation bias or memory bias and worry may be more beneficial when investigating individual cognitive processes to target for specific interventions. An important next step for future research would be to assess the predictive magnitude of poly-bias scores and whether a combination of cognitive biases explain more variance in worry than individual biases alone. This has the potential to inform future research on the cognitive mechanisms to target for early interventions and tailor current treatments in adolescents, in particular if cognitive biases are processes that work closely together.

The current results provide preliminary support for the potential cognitive mechanisms that may be beneficial to target in early interventions for adolescent worry. In particular, individual cognitive biases such as positive interpretation bias, negative interpretation bias, and negative memory bias were processes associated with worry. In addition, the study showed that a combination of negative or positive biases, may be important cognitive processes to target in adolescent worry. Perhaps implementing cognitive strategies in healthy adolescents through school programmes and curriculums, could have long-term benefits in teaching adolescents how to manage maladaptive cognitive biases before they develop into pathological worry. However, further research examining the causal relationship between cognitive biases and worry is needed to better understand the mechanisms that contribute to adolescent worry and improve interventions.

Future studies should aim to examine the interplay between multiple cognitive biases in adolescence, with growing evidence to suggest that these cognitive processes influence each other and may not operate in isolation. The poly-bias approach may offer a more parsimonious method of investigating the combined cognitive bias hypothesis and future research replicating this method and comparing it to the individual bias approach is needed. The current study provides preliminary support for the combined cognitive bias hypothesis in adolescence and advances our knowledge of how these cognitive processes influence adolescent worry.

Interpretation and memory biases play an important role in adolescent worry and are closely interrelated cognitive processes. As this was the first study to investigate the relationship between cognitive biases and adolescent worry, it is clear that further research on the cognitive mechanisms associated with worry in adolescents is needed. Experimental and longitudinal studies that examine how cognitive biases develop over time would provide greater insight into the causal mechanisms to identify as potential cognitive targets to improve current treatments for worry in adolescents. Further exploration of the combined cognitive bias hypothesis in adolescents is needed to investigate how these processes develop and work together. Adolescence represents a period of significant cognitive, developmental, physiological, and social changes, therefore a deeper understanding of the cognitive mechanisms underlying worry is crucial for improving treatments and early interventions that may help prevent long-term consequences in adulthood.

Chapter 4

4

The Development of Cognitive Biases and Worry in Adolescents: A Longitudinal Study

One of the limitations in the child and adolescent literature on worry is that studies are typically correlational in design. The research presented in this chapter addressed this gap in the literature and investigated the causal relationship between cognitive biases and worry in adolescents over time. Data was drawn from adolescents in the CogBias Longitudinal study at time point one (N = 504) and follow-up data at time point two (N = 450). A cross-lagged panel model using structural equation modelling examined the stability and direction of causality between cognitive biases and worry from early to mid-adolescence. In light of the combined cognitive bias hypothesis, we examined the interrelationships amongst attention bias, interpretation bias, and memory bias in adolescents and how this influenced worry over time. The results showed that Negative Bias in early adolescence predicted worry at mid-adolescence. Whilst the reverse relationship was also significant, as worry in early adolescence predicted Negative Bias at mid-adolescence. There was no evidence to suggest that a Positive Bias or Attention Bias in early adolescence predicted worry in mid-adolescence. In addition, Negative Bias, Positive Bias, and worry remained stable cognitive processes from early to mid-adolescence.

4.1. Introduction

Cognitive theories propose that anxious individuals hold cognitive schemas that selectively direct processing resources towards danger or threat (Beck et al., 1985, 1979; Crick & Dodge, 1994; Daleiden & Vasey, 1997; Field et al., 2011; Kendall, 1985; Muris & Field, 2008; Murray et al., 2009; Vasey & Daleiden, 1994; Williams et al., 1997). These cognitive biases, such as selective attention towards threat, the tendency to interpret ambiguous information in a threatening or negative way, and the memory recall of threat-related stimuli, has been shown to play a detrimental role in the onset and maintenance of worry and GAD in adults (Cisler & Koster, 2010; Hayes et al., 2010; Hirsch et al., 2009; Mathews & MacLeod, 2005; MacLeod et al., 1986). However, few studies have investigated how these cognitive biases operate during worry and GAD in adolescents and importantly, how these cognitive processes develop over time. Given that worry is common in adolescents, a better understanding of how worry develops into the excessive and uncontrollable worries observed in GAD, would help to identify potential targets for treatments and early interventions.

As reviewed in Chapter Two, only a relatively small number of studies have examined the relationship between cognitive biases and symptoms of worry and GAD in children and adolescents. Evidence shows that youth with high worry and GAD selectively attend to threatening stimuli (Dalgleish et al., 2003; Eschenbeck et al., 2004; Taghavi et al., 1999; 2003; Waters et al., 2008; 2014), tend to interpret ambiguous information as threatening or negative (Bogels et al., 2003; Taghavi et al., 2000; Suarez & Bell-Dolan, 2001; Suarez-Morales & Bell, 2006), although do not tend to recall more threat-related words in a memory recall task (Dalgleish et al., 2003), compared to non-anxious youth. However, one limitation to the systematic review and to the current literature in general, is that studies often combine child and adolescent populations, which make it difficult to disentangle age related effects and evaluate whether these cognitive processes develop differently throughout childhood and adolescence. A second limitation is that only a few studies have examined the direct relationship between worry and cognitive biases in non-clinical samples, which have all been conducted in children (Eschenbeck et al., 2004; Suarez & Bell-Dolan, 2001; Suarez-Morales & Bell, 2006). Therefore, research on the cognitive biases underlying adolescent worry remains largely unexplored and further investigation of the worry process in healthy adolescents would provide insight into how negative intrusive thoughts can sometimes develop into the pathological worry seen in GAD.

The study in Chapter Three addressed this gap in the literature and investigated the association between worry and attention, interpretation, and memory biases in a large sample of healthy adolescents with varying levels of worry. The study found that high worry was associated with negative interpretation and negative memory bias, whilst low worry was related to positive interpretation and positive memory bias. There was no evidence to support an association between worry and attention bias in adolescents. This suggests that interpretation and memory biases are cognitive processes that play an important role in adolescent worry. Although, as the previous study was correlational, the ability to draw causal inferences about whether cognitive biases cause worry or whether worry leads to cognitive biases is limited. Investigating how attention, interpretation, and memory biases develop in healthy adolescents over time would provide useful insight into the risk and protective mechanisms that cause emotional vulnerability before they become fully manifested in pathological worry.

Longitudinal studies exploring the nature and developmental course of worry throughout childhood and adolescence are lacking. Recently, the Avon Longitudinal Study of Parents and Children (ALSPAC), investigated the normal development of worry and the associated distress in a large community sample of youth (N = 2227) at three time points from the ages of 7 to 13 (Caes et al., 2016). The longitudinal study relied on mother's self-report measures on their child's level of worry and mother's observations on the impact of worry on daily functioning. The study found that worry peaked at the age of 10 and children showed low control over their worries. In addition, the highest level of emotional disruption from worry occurred at the age of 10 and interference in daily activities due to worries was highest at the age of 13, in particular for girls. This indicates that levels of worry can increase over time and has a detrimental effect on daily functioning during early adolescence. Moreover, the results suggest that early adolescence is a vulnerable period for worry, which may relate to advanced cognitive development and maturation (Vasey, 1993). To date, this is the only longitudinal study that has examined the development of normal worry from childhood to early adolescence. Thus, longitudinal research investigating the role of cognitive biases in the trajectory of worry from early, mid, to late adolescence is crucial to understanding the cognitive pathways involved in the aetiology of pathological worry and anxiety (Cicchetti & Rogosch, 2002).

As discussed in Chapter Two, Hirsch and Matthews' cognitive model of pathological worry (2012) provides a useful evidence-based framework for understanding the causal role of cognitive biases and executive functions in the manifestation of worry and GAD. However, no studies have addressed how attention, interpretation, and memory biases develop in adolescents over time. In addition, the interplay amongst these cognitive biases are not well understood, with attention, interpretation, and memory biases often studied in isolation rather than examining how they combine to maintain psychopathology. A growing body of empirical work has begun to investigate cognitive biases in an integrative manner to support the combined cognitive bias hypothesis (Hirsch et al., 2006), which proposes that multiple cognitive biases interact and influence each other at various stages of the cognitive system and that it is this co-interaction that maintains and exacerbates psychopathology.

A number of studies conducted in adults with clinical and subclinical levels of depression and anxiety have shown the functional relationships and dependence amongst attention, interpretation, and memory biases (Hertel & El-Messidi, 2006; Hertel et al., 2008; Ellis, Beevers, & Wells, 2011; Everaert et al., 2014; Koster et al., 2010; Salemink et al., 2010; Tran et al., 2011). However, the literature pertaining to the combined cognitive bias hypothesis in children and adolescents has lagged behind (Higa & Daleiden, 2008; Klein et al., 2017; Orchard & Reynolds, 2018; Vassilopoulos, 2012). As demonstrated in Chapter Three, preliminary evidence using poly-bias scores suggests that interpretation and memory biases are closely interrelated cognitive processes in adolescents and are associated with worry. In contrast, attention bias was not related to either interpretation or memory bias in our sample of adolescents. A deeper understanding of how these cognitive processes develop over time and influence each other in the onset and maintenance of worry in adolescents, would help to identify the causal mechanisms involved in pathological worry and anxiety in youth (Cartwright-Hatton, 2006)

This has important clinical implications as research indicates that approximately 50-80% of youth with anxiety disorders receiving cognitive behavioural therapy (CBT) show meaningful reductions in anxiety symptoms following treatment (Cartwright-Hatton, Roberts, Chitsabesan, Fothhergill, & Harrington, 2004; James, Soler, & Weatherall, 2007; Kendall, Settipani, & Cummings, 2012). Whilst this is encouraging, a large percentage of youth do not respond to treatment, and in some cases, anxiety symptoms continue to persist following initial improvements (Compton, Burns, Egger, & Robertson, 2002). Researchers suggest that a potential reason for suboptimal remission rates for GAD in youth is that trans-diagnostic CBT treatments do not address the underlying cognitive mechanisms that have been empirically associated with pathological worry (Holmes, Donovan, & Farrell, 2015; Holmes, Donovan, Farrell, & March, 2014; Leger, Ladouceur, Dugas, & Freeston, 2003; Payne, Bolton, & Perrin, 2011). In CBT for anxious youth, some cognitive biases are targeted through fear extinction and cognitive restructuring, which uses behavioural techniques to challenge maladaptive cognitive appraisals. However, other cognitive biases may be less directly targeted in current treatments or in standardised interventions (Lau & Waters, 2016). In recent years, the development of innovative CBM approaches aim to target more specific cognitive processes such as attention or interpretation bias, however findings on the efficacy of CBM in anxious youth have been mixed (Lau, 2013; Lau, 2015; Krebs et al., 2018). Therefore, a better understanding of the cognitive biases that underpin the aetiology of worry in adolescents would help to develop more targeted treatments and interventions for GAD in youth.

The aim of the present study was to investigate the causal relationship between cognitive biases and worry in adolescents over time. Specifically, we examined whether cognitive biases or worry causally precedes the other using data from the CogBias Longitudinal study collected at two time points (T1 and T2; *M time lag* = 15 months). A cross-lagged panel analysis was conducted using structural equation modelling (SEM) to explore the causal ordering between cognitive biases and worry and to determine the direction of causal effects. In line with the combined cognitive bias hypothesis, we use poly-bias scores – a score comprised of a combination of cognitive biases - to investigate whether biases may be interrelated and work together in the manifestation of psychopathology. A better understanding of the causal nature of the relationship between worry and cognitive biases would help shed light on the causal pathways and strength of the associations over time. Therefore, the present study addressed the following research questions:

1) To examine the interrelationships amongst attention, interpretation, and memory biases in mid-adolescence (T2) to create poly-bias scores

2) To investigate whether poly-bias scores and worry remain stable from early adolescence (T1) to mid-adolescence (T2)

3) To examine whether poly-bias scores in early adolescence (T1) predict levels of worry in mid-adolescence (T2) and/or do levels of worry in early adolescence (T1) predict poly-bias scores at mid-adolescence (T2)

Firstly, we hypothesised that the factor structure of the principle components analysis (PCA) conducted at T1 to derive poly-bias scores (see Chapter Three) would be consistent at T2 of the CogBias Longitudinal study. That is, we predict negative interpretation and negative memory bias would be highly correlated; positive interpretation and positive memory bias would be strongly associated; and that the attention bias variables would be correlated with one another, but not with either interpretation or memory bias variables. Secondly, we predicted that worry and the presence of a Negative Bias and Positive Bias would remain stable processes across time from early to mid-adolescence. Thirdly, we hypothesised that Negative Bias and Positive Bias are cognitive mechanisms that precede worry in the direction of causal pathways. Therefore, we predicted that Negative Bias in early adolescence would cause high worry in mid-adolescence, whilst Positive Bias in early adolescence would predict low worry in mid-adolescence. In line with the findings of Chapter Three, we do not expect attention bias to predict worry in adolescents across time.

4.2. Method

Participants

Participants were 450 adolescents (56% females) aged 13 to 16 years old (*M* = 14.55, *SD* = .63), who attended secondary schools in the South England area. The sample comprised of adolescents participating in the CogBias Longitudinal study at time point 2 (T2), which was approximately 12 to 18 months after data collection at time point 1 (T1). The drop-out rate at T2 was 11% (*n* = 54) due to school absences on the day of testing or students leaving the school. The sample was drawn from ten cohorts in nine different schools, comprising both private and comprehensive schools, thereby ensuring a diverse socioeconomic and cultural mix of participants. All nine schools that participated in T1 were retained at T2. For a detailed description of the study design and demographic information such as ethnicity, household size, parental education and occupation, see Chapter Three. Participation at T2 was voluntary and adolescents were compensated by means of a £10 Amazon voucher at the end of the session.

Procedure

The head teacher or psychology teacher from the schools participating in the CogBias Longitudinal study were contacted approximately 12 months after data collection at T1. Testing sessions were organised by each individual cohort and due to school constraints with scheduling, data collection at T2 was between 12 to 18 months after T1 (*M time lag* = 15 months). The testing sessions were conducted in small groups in computer labs at participating schools or at the Department of Experimental Psychology, University of Oxford. The testing procedure was identical to T1, where participants completed questionnaires and cognitive tasks for two hours under exam conditions, with a short break after the first hour. Additional questionnaires were added at T2 to assess working memory, attentional control, high sensitivity, and binge eating. During the session, height and weight was also measured individually with a researcher in a private room to assess BMI.

Measures

In Chapter Four, only data that are relevant for the current study's research questions and consistent with Chapter Three were analysed. For a complete description of the overall measures and design of the larger, longitudinal study see Booth, Songco et al., 2017.

Self-report measures

Demographic questionnaire. Parent self-report on a demographic questionnaire assessed information such as adolescent's age, gender, ethnicity, household size, parent's education and occupation. Information pertinent to SES included household size, mother and father's occupation, and mother and father's level of education. In line with the literature and the previous chapter, parental education was used as a reliable proxy of SES (Buchmann, 2002; Hauser, 1994; Hoff et al., 2002; Yang & Gustafsson, 2004). In the present study, we created an index of SES by calculating the mean score of mother and father's highest level of education attained. In addition, to account for differences at the school level in our sample, we created a variable based on the number of cohorts in the study (i.e. ten cohorts). This school variable encapsulates the different schools, year levels, time of year that the testing sessions were conducted, and the various time lags between the testing sessions in schools. In our analyses, we control for gender, school, and SES as covariates.

Worry. The Penn State Worry Questionnaire for Children (PSWQ-C) (Chorpita et al., 1997) is a 14 item self-report measure used to assess the tendency to worry in children aged 6 to 18 years old (see Appendix B). Examples of items include “My worries really bother me” and “I know I shouldn’t worry, but I just can’t help it.” Each item was rated on a 4-point Likert scale (0 = Never true to 3 = Always true) and a Worry Total Score was calculated by summing the items. Higher scores on the PSWQ-C indicate more frequent and uncontrollable worries. In adolescent samples, the PSWQ-C has excellent internal consistency, good convergent and discriminant validity, and test-retest reliability in clinical and non-clinical samples (Chorpita et al., 1997; Pestle et al., 2008). The internal consistency on the PSWQ-C for the current study was good ($\alpha = .81$).

Cognitive tasks

Attention bias. A visual Dot-probe task (MacLeod et al., 1986) with faces assessed attention bias to three separate emotional categories. Threat bias was assessed with angry faces, positivity bias was assessed with happy faces, and empathy bias was assessed with pain faces. The task comprised three blocks corresponding to each of these categories. Within each emotion block 56 trials presented an emotional face paired with a matched neutral face (same actor) for 500ms, followed by a probe for 3000ms either behind the emotional face (congruent trials) or behind the neutral face (incongruent trials), therefore attention bias for emotion could be inferred if reaction time (RT) was faster on congruent trials compared to incongruent trials (see Appendix C). The faces were chosen from the STOIC faces database (Roy et al., 2007) which is a validated set of ten actors expressing six basic emotions. We selected seven actors (four male, three female) and four emotions (neutral, anger, happiness, pain) to make up our task of 168 trials, with each actor shown eight times in each block. The faces were presented in greyscale with no hair or jawline showing on a grey background. Pictures were 230 x 230 pixels in size and presented approximately ten degrees visual angle apart. Probes were the letters ‘Z’ and ‘M’ corresponding to the correct response, which were presented equally on the left or right, to increase task difficulty and encourage attentional engagement. The inter-trial interval (ITI) was 500ms, followed by a fixation cross presented for 500ms to signal the start of a new trial. Participants were instructed to focus on the fixation cross and ignore the faces, but respond to the probe as fast as they could, without compromising their accuracy. An error message was shown if participants made an incorrect response or if no response was made within 3000ms. Block order was counterbalanced across participants and a rest period of 30000ms with a timer was displayed between blocks. Participants also completed a practice block with 8 trials depicting only the probe and 16 trials with neutral-neutral face pairings, which were not analysed.

After the data was prepared, we calculated each participants mean RT for each emotional condition and trial type. Bias indices were calculated separately for threat, positivity, and empathy, as the difference in RT between congruent and incongruent trials (high numbers reflected attentional orienting). Therefore, we created six variables (angry congruent, angry incongruent, pain congruent, pain incongruent, happy congruent, and happy incongruent) and calculated a bias index score for each emotional condition (angry, pain, and happy). Robust split-half reliabilities (Parsons, 2017) for the bias indices were low; Angry bias = .06 (Spearman-Brown corrected .10), Happy bias = .10 (Spearman-Brown corrected .18), and Pain bias = .06 (Spearman-Brown corrected .12).

Interpretation bias. The Adolescent Interpretation and Belief Questionnaire (AIBQ; Miers et al., 2008) was used to assess interpretation bias to hypothetical positive and negative social and non-social situations. Participants read ten ambiguous scenarios and were asked to imagine that the situations were happening to them, they were then shown three thoughts that could arise in response to the situation and asked to rate how much each thought would be likely to pop into their head using a 5-point Likert scale (1 = Does not pop in my mind, 3 = Might pop in my mind, 5 = Definitely pops in my mind) (see Appendix D). The interpretations for each scenario were either neutral, positive or negative. Interpretations for each situation were presented in a fixed random order. Outcome variables were created for Positive Interpretation (Social) as the summation of the ratings on the positive social interpretations divided by the five social situations, for Negative Interpretation (Social) as the summation of the ratings on the negative social interpretations divided by the five social situations, for Positive Interpretation (Non-Social) as the summation of the ratings on the positive non-social interpretations divided by the five non-social situations, and for Negative Interpretation (Non-Social) as the summation of the ratings on the negative non-social interpretations divided by the five non-social situations. These outcome measures were calculated to adhere to the original study and most previous research with the AIBQ (Kingsbury & Coplan, 2016; Miers et al., 2008; Miers, et al., 2013). Internal consistency (Cronbach's α) varied for each subscale. The internal consistency for the Positive Interpretation (Social) subscale was α = .54, Negative Interpretation (Social) subscale was α = .81, Positive Interpretation (Non-social) was α = .54, and Negative Interpretation (Non-social) was α = .54, which is in line with previous literature.

Memory bias. The Self-referential Encoding Task (SRET; Hammen & Zupan, 1984) was used to assess memory bias for self-referential words. The task comprised three phases – an encoding phase, a distraction phase, and an incidental free recall phase. In the encoding phase, self-referent adjectives were displayed on the screen for 200ms, followed by the caption "Describes me?" which was presented below the word at which point participants could respond with either yes or no using the “Y” and “N” keys. A new word was presented after a valid response was made. The word list comprised of 22 positive (e.g. “cheerful”, “attractive”, “funny”) and 22 negative (e.g. “scared”, “unhappy”, “boring”) self-referent adjectives that had been previously validated for use in an adolescent sample and had been matched on word length and recognisability (Hammen & Zupan, 1984). See Appendix E for word stimuli. In the distraction phase, participants were instructed to solve three simple mathematics equations by typing their response into a short answer box. Responses did not have to be correct and were not analysed. In the incidental free recall phase, participants were instructed to type as many words as they could remember from the “Describes me” task, regardless of whether they endorsed the word, into a long answer box. They were given three minutes for recall, at which point the task ended. We produced a negative and positive memory bias score to calculate negative memory bias as the total number of negative words that were endorsed and recalled, and positive memory bias as the total number of positive words that were endorsed and recalled (Asarnow et al., 2014).

Data Analysis Plan

Principle components analysis

Identical to the procedure conducted in Chapter Three, a PCA with oblimin rotation was performed to reduce the nine cognitive bias variables at T2 to create composite bias scores, which we refer to as poly-bias scores. The variables were drawn from the Dot-probe (i.e. Angry bias, Pain bias, and Happy bias indices), the AIBQ (i.e. Negative Interpretation (Social), Negative Interpretation (Non-social), Positive Interpretation (Social), and Positive Interpretation (Non-social) subscales), and the SRET (i.e. Negative memory bias and Positive memory bias). This novel method allows the examination of the interrelationships among the cognitive biases (Orchard & Reynolds, 2017, unpublished manuscript). We investigated whether the factor structure of the PCA conducted at T1 (Chapter Three) yielded a consistent factor structure at T2 and whether the cognitive biases behaved in a similar way in adolescence over time. Poly-bias scores created at T2 and those consistent with the poly-bias scores produced at T1, were then used in the cross-lagged panel analysis to examine the causal relationship between cognitive biases and worry in adolescence. For details on the method of the PCA and creating poly-bias scores refer to Chapter Three. The PCA and all correlations and bivariate analysis were conducted using SPSS Statistical Software Package (version 25). An alpha level of .05 was set for all statistical tests.

Structural equation modelling was used to examine the causal relationship between cognitive biases and worry in adolescents across T1 and T2 of the CogBias Longitudinal study. Specifically, we used a cross-lagged panel model to specify auto-regression effects and cross-lagged effects amongst poly-bias scores and worry over time (Figure 4.1). The cross-lagged panel model estimates the reciprocal causal relationship between poly-bias scores and worry across T1 and T2 (i.e. cross-lagged effects). If the cross-lagged path is significant in one direction but not the other, findings are consistent with the hypothesis that the causal effect works in one direction, but not the other. If neither cross-lagged path is significant, then the results do not indicate causation for either direction. However, results may indicate that both of the cross-lagged pathways are significant, which suggest that the causal direction of effects work in both ways. In addition to cross-lagged pathways, the model assesses the stability of both poly-bias scores and worry across T1 and T2 (i.e. auto-regression effects) to demonstrate the strength of the repeated measure over time.

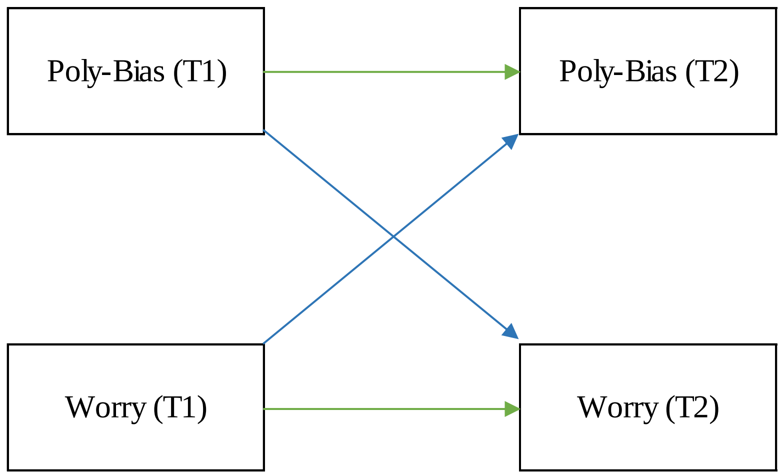

Figure 4.1. Simple cross-lagged panel model highlighting autoregressive effects (green lines) and cross-lagged effects (blue lines)

Cross-lagged panel models

For the analysis, separate cross-lagged panel models were constructed for each of the individual poly-bias scores created at T2 to investigate the causal relationship with worry. Both worry and poly-bias scores were treated as observed variables as they involved repeated measures at T1 and T2. Gender, school, and SES were included as covariates in the cross-lagged panel model in order to control for potential confounders in the causal relationship between worry and cognitive biases. Unidirectional arrows represent causal links, whilst double headed arrows represent correlations between the covariates. Given the previous literature on the association between gender and worry, paths were estimated from gender to worry and poly-bias scores at T1 and T2 to account for the causal effect of the covariate on either outcome. Furthermore, the inclusion of the covariance between predictor variables ensures that path coefficients are partial effects controlling for the other variable. The inclusion of measurement errors correlated across time points is a good statistical practice when modelling longitudinal data and accounts for the assumption that measurement errors of a repeated measure may co-vary over time (Pitts, West, & Tein, 1996).

The model-fit for each of the cross-lagged panel models were evaluated using multiple indices such as the Root Mean Square Error of Approximation (RMSEA), the Tucker-Lewis Fit Index (TLI), the Comparative Fit Index (CFI); and the Normed Fit Index (NFI). These model-fit indices were selected as they are robust to sample size and suitable for large samples in comparison to the conventional chi-square test (χ^2), which can be easily distorted by large samples (Bentler, 1990). RMSEA values less than 0.05 are considered a good model-data fit and less than 0.08 an adequate fit, whilst TLI, CFI, and NFI values greater than 0.95 indicate good model fit and values greater than 0.90 an adequate fit. The cross-lagged panel analysis was conducted using the statistical programme AMOS (Analysis of Moment Structures, version 25; Arbuckle, 2017).

Missing data

There was no missing data for participants on the PSWQ-C, AIBQ, and SRET (N = 450). Five participants were excluded from the Dot-probe task for performing at less than 70% accuracy (N = 445). Error trials were excluded from the dot-probe analysis (6% of trials), as well as trials with RT's faster than 200ms or slower than 3000ms (<1% of trials) to remove trials reflecting pre-emptive responses or delayed responses, respectively. We also removed response latencies that were three *SD's* from each participant's mean RT for each emotional condition and congruency type (1% of trials). In addition, SES data was missing for 19 participants.

The imputation process of the maximum likelihood (ML) estimation was used to deal with missing data. The maximum likelihood estimation is a common method used to treat missing values in longitudinal studies using cross-lagged panel analysis (Allison, Williams,

& Moral-Benito, 2017; Ma & Xu, 2004; Straatmann, Almquist, Oliveira, Rostila, & Lopes, 2018). Evidence shows that ML is the most pragmatic missing data estimation approach for structural equation modelling and has greater statistical efficiency than conventional methods of dealing with missing data (Little, Schnabel, & Baumert, 2000).

4.3. Results

Descriptive Statistics at Time Point 2

Descriptive statistics of the sample are presented in Table 4.1. The mean level of worry for the sample at T2 (M = 18.64, SD = 7.07) is in line with previous studies in adolescent non-clinical samples using the PSWQ-C (*M range* = 15.29 to 19.24) (Chorpita et al., 1997; Dugas, Laugesen, & Bukowski, 2012; Pestle et al., 2008). The mean level of worry reported on the PSWQ-C at T2 (M = 18.64) was lower than the mean level of worry reported at T1 (M = 21.74) of the CogBias Longitudinal study. In addition, females (M = 19.78, SD = 7.21) showed higher levels of worry compared to males (M = 17.21, SD = 6.64), $t(448) = -3.90$, p <.001; d = 0.40), which is consistent with T1 and gender differences of worry in the previous literature. No significant correlations were observed between age and worry, as well as SES and worry (ps >.05). A one-way ANOVA revealed a statistically significant difference in mean levels of worry among the school cohorts ($F(9,440) = 3.09$, p =.001, partial η^2 =.60). As shown in the previous chapter, there was a significant difference between school cohorts and SES ($F(9,475) = 13.29$, p <.001, partial η^2 =.20). Therefore, in the structural equation model, we included gender, school, and SES as covariates.

Table 4.1

Sample Characteristics for the CogBias Longitudinal Study (Time Point 2) by Cohort

Variable	Total	1	2	3	4	5	6	7	8	9	10
N	450	26	9	60	40	6	25	108	101	51	24
Mean Age (SD)	14.55 (.63)	14.02 (.05)	13.35 (.27)	14.47 (.28)	14.79 (.29)	13.50 (.15)	14.03 (.30)	15.06 (.39)	14.15 (.33)	15.35 (.26)	14.30 (.30)
Year group	8 - 10	8	8	9	10	9	9	10	9	10	9
Gender (% females)	56	56	52	100	100	100	44	0	100	0	58
Mean Worry (SD)	18.64 (7.01)	16.89 (4.62)	16.52 (6.83)	18.97 (7.19)	22.23 (6.87)	18.83 (8.93)	16.48 (7.25)	18.03 (6.94)	19.08 (7.11)	16.63 (6.19)	22.13 (6.89)
Height cm (SD)	166.61 (8.79)	163.39 (6.47)	160.94 (7.57)	161.98 (5.94)	164.32 (6.57)	159.92 (6.74)	164.80 (8.12)	175.49 (7.36)	163.36 (6.05)	174.68 (7.60)	164.29 (7.99)
Weight kg (SD)	57.78 (11.16)	55.99 (6.06)	51.75 (9.33)	55.55 (10.14)	60.29 (13.65)	55.12 (5.87)	57.33 (14.97)	63.84 (9.31)	54.48 (9.42)	61.68 (11.47)	55.95 (10.17)
BMI (SD)	20.69 (3.18)	20.96 (1.89)	19.91 (2.96)	21.16 (3.55)	21.81 (3.99)	21.80 (4.33)	20.95 (4.37)	20.67 (2.29)	20.37 (2.96)	20.09 (2.78)	20.71 (3.39)

Note. Column numbers indicate cohort number; Worry = Penn State Worry Questionniare - Child version (PSWQ-C)

Table 4.2

Correlations of Worry with Cognitive Bias Variables

Variable	1	2	3	4	5	6	7	8	9
1. Worry									
2. Angry Bias	.04								
3. Pain Bias	.00	-.05							
4. Happy Bias	-.07	.08	-.04						
5. Negative Interpretations_social	.50**	-.05	.02	-.01					
6. Negative Interpretations_non-social	.44**	.02	.04	.02	.62**				
7. Positive Interpretations_social	-.20**	-.01	-.01	-.04	-.21**	-.01			
8. Positive Interpretations_non-social	-.13**	-.05	.05	.10*	.01	.46**	-.04		
9. Negative Memory bias	.46**	.02	-.01	.03	.46**	-.27**	.37**	-.22**	
10. Positive Memory bias	-.27**	-.06	-.01	-.02	-.30**	.38**	-.15**	.27**	-.26**

Note. * p<.05 **p <.01

Principle Components Analysis

Correlations between the cognitive bias variables and worry at T2 are presented in Table 4.2. The results showed small to moderate associations between interpretation bias and memory bias. Furthermore, worry was significantly associated with interpretation bias and memory bias. However, attention bias was not significantly associated with interpretation bias, memory bias or worry (*ps* >.05). The correlations at T2 demonstrate a similar pattern to the correlations found at T1. Despite previous studies suggesting that items that do not correlate with other items should be excluded in a PCA, for the purpose of this analysis and in line with the analysis conducted in Chapter Three, we included the attention bias variables in order to compare whether the cognitive biases yielded a consistent factor structure in adolescents over time.

The results of the PCA are presented in Table 4.3. The Kaiser-Meyer-Olkin measure of Sampling Adequacy (KMO = .610) and Bartlett's test of sphericity ($\chi^2(36) = 639.54$, $p < .001$) indicated that the sample size and the data were adequate for conducting PCA. The analysis yielded three factors with eigenvalues greater than one and explained 55% of the total variance. Factor one (eigenvalue = 2.37) accounted for 26% of the variance, factor two (eigenvalue = 1.47) accounted for a further 16% of the variance, whilst factor three (eigenvalue = 1.12) accounted for 12% of the total variance.

The pattern of factor loadings revealed three factors identical to the factor structure at T1 (see Chapter Three). Factor one was interpreted as *Negative Bias* and comprised of high factor loadings of the variables: negative interpretations of social scenarios, negative interpretations of non-social scenarios, and negative memory bias. Factor two was identified as *Positive Bias* due to moderate to high factor loadings of the variables: positive interpretations of social scenarios, positive interpretations of non-social scenarios, and positive memory bias. Factor three was related to *Attention Bias* towards emotional stimuli and included high factor loadings of the variables: angry bias, pain bias, and happy bias. The variable negative memory bias loaded on both factor one and factor two, however conceptually and statistically it was more meaningful to include in Factor one (Negative Bias). Based on the outcome of the PCA, we calculated factor scores by summing the weighted betas of the relevant items to create three poly-bias scores (Negative Bias, Positive Bias, and Attention Bias). For example, to compute the factor score for a given case for a given factor, the case's standardized score on each variable is multiplied by the corresponding weighted beta of the variable for the given factor, and sums these products.

Table 4.3

Factor Loadings for Principle Components Analysis on Cognitive Bias Variables

Item	Negative Bias	Positive Bias	Attention Bias
Negative Interpretations_social	.88		
Negative Interpretations_non-social	.87		
Negative Memory Bias	.62	-.32	
Positive Interpretations_social		.81	
Positive Interpretations_non-social		.81	
Positive Memory Bias		.59	
Angry Bias			.66
Pain Bias			-.50
Happy Bias			.66

Note. Principle Components Analysis using Oblimin rotation; Factor loadings < .03 are omitted

Cross-lagged Panel Analysis

Cross-lagged panel model with negative bias and worry

A cross-lagged panel model investigated the causal relationship between Negative Bias and worry in adolescents, controlling for the effects of gender, school, and SES (Figure

4.2). The model fit indices demonstrated a good fit between the model and the data; RMSEA = .04, NFI = .98, TLI = .97, CFI = .99. The results showed that the auto-regressive pathways for Negative Bias from T1 to T2 (β = .50, p <.001) and worry from T1 to T2 (β = .61, p <.001) were significant, indicating that they were highly stable over time. The cross-lagged pathway for Negative Bias at T1 predicting worry at T2 (β = .10, p <.001) was significant. In addition, the cross-lagged pathway for worry at T1 predicting Negative Bias at T2 (β = .10, p = .020) was also significant. These results suggest that the direction of the relationship between worry and Negative Bias works in both ways, as worry in early adolescence predicts Negative Bias in mid-adolescence, and Negative Bias in early adolescence also predicts worry in mid-adolescence.

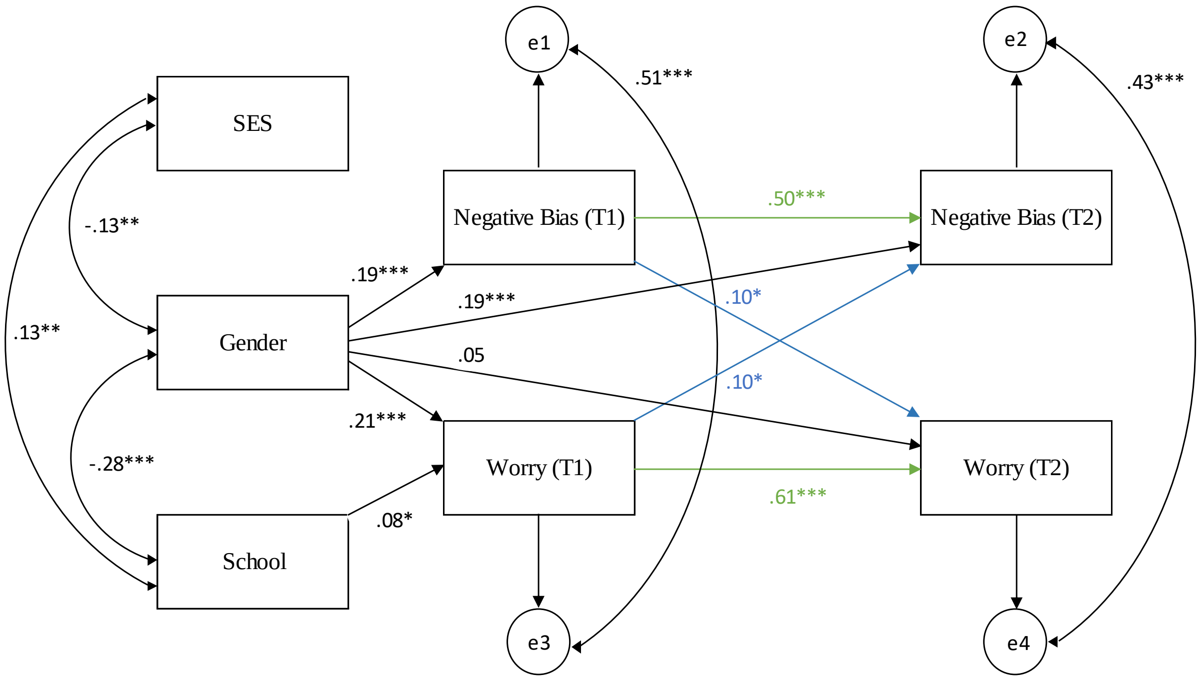

Figure 4.2. Cross lagged panel model estimating the causal relationship between Negative Bias and Worry from early to mid-adolescence
Note: Rectangles represent observed variables, unidirectional arrows represent causal links and double headed arrows represent covariances. All parameter estimates for unidirectional paths are standardized
[a] *p <.05 **p <.01 ***p <.001

Cross-lagged panel model with positive bias and worry

A cross-lagged panel model was tested to examine the causal direction between Positive Bias and worry in adolescents, controlling for gender, school, and SES (Figure 4.3). The overall fit of the model to the data was good; RMSEA = .06, NFI = .97, TLI = .91, CFI = .98. Results showed that the auto-regressive pathways for Positive Bias from T1 to T2 (β = .48, *p* <.001) and worry from T1 to T2 (β = .64, *p* <.001) were significant, indicating that they were highly stable over time. However, neither cross-lagged effect was significant, suggesting that Positive Bias in early adolescence does not predict subsequent worry in mid-adolescence (β = .05, *p* =.151) and worry in early adolescence does not predict Positive Bias in mid-adolescence (β = .003, *p* =.951). The results do not support the possibility of a causal effect in either direction between Positive Bias and worry in adolescents.

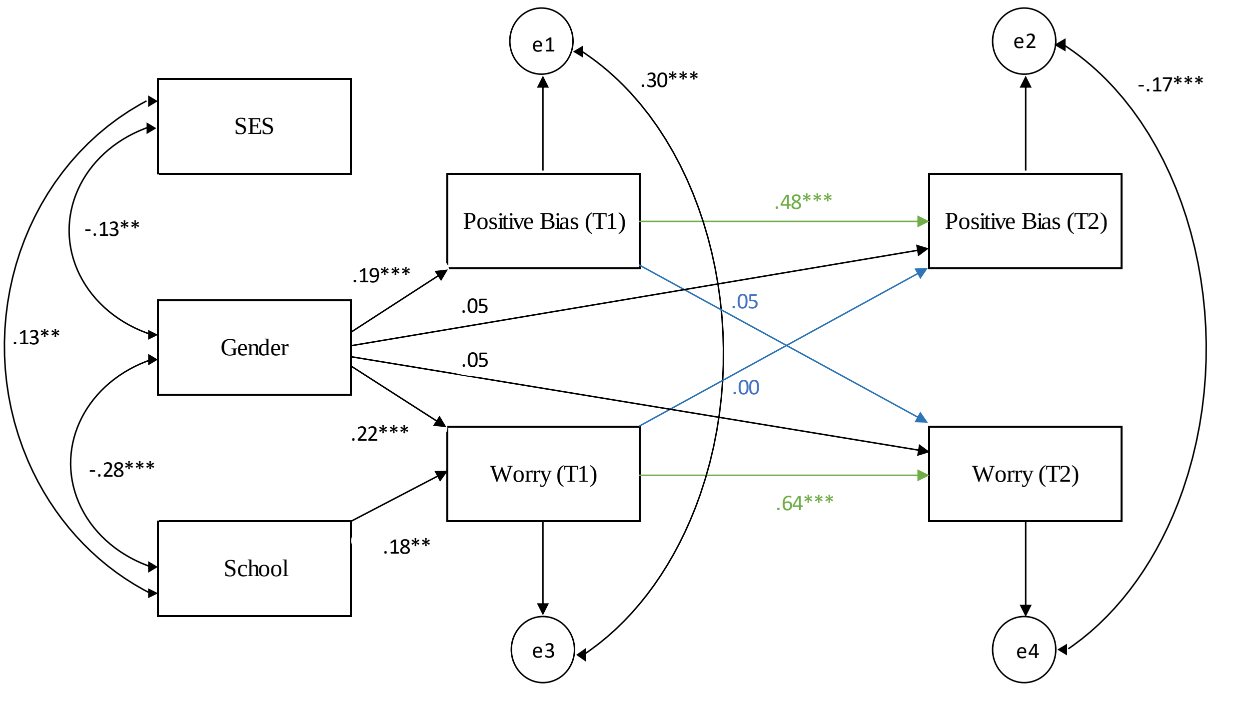

Figure 4.3. Cross lagged panel model estimating the causal relationship between Positive Bias and Worry from early to mid-adolescence

Note: Rectangles represent observed variables, unidirectional arrows represent causal links and double headed arrows represent covariances. All parameter estimates for unidirectional paths are standardized.

*p <.05 **p <.01 ***p <.001

Cross-lagged panel model with attention bias and worry

A cross-lagged panel model examined the nature of the causal relationship between Attention Bias and worry in adolescents, controlling for the effects of gender, school, and SES (Figure 4.4). The model fit indices demonstrated a good model-data-fit; RMSEA = .02, NFI = .98, TLI = .99, CFI = .99. The results showed that the auto-regressive path for worry (β = .65, *p* <.001) was significant, indicating that worry was highly stable over time. However, the auto-regressive path for Attention Bias was not significant (β = -.02, *p* =.736), which suggests that Attention Bias was not stable across time. Furthermore, neither cross-lagged effect was significant, indicating that Attention Bias in early adolescence does not predict worry in mid-adolescence (β = .05, *p* =.128) and worry in early adolescence does not cause Attention Bias at mid-adolescence (β = -.01, *p* =.842). The results do not support the possibility of a causal effect in either direction between Attention Bias and worry in adolescents.

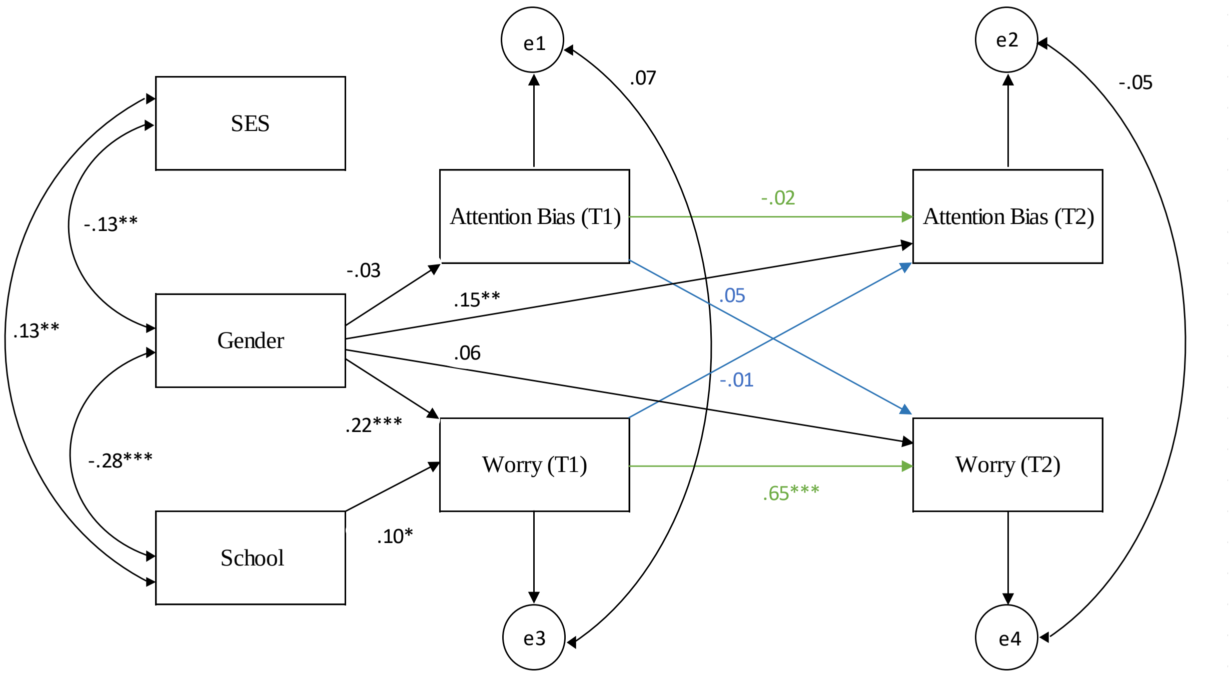

Figure 4. 4. Cross lagged panel model estimating the causal relationship between Attention Bias and Worry from early to mid-adolescence

Note: Rectangles represent observed variables, unidirectional arrows represent causal links and double headed arrows represent covariances. All parameter estimates for unidirectional paths are standardized.

*p<.05 **p<.01 ***p<.001.

4.4. Discussion

The current study investigated the direction of causality between worry and a combination of cognitive biases in adolescents across time. As hypothesised, the factor structure of the PCA examining the relationship amongst attention, interpretation, and memory biases in mid-adolescence (T2), showed a similar pattern of results to that observed in early adolescence (T1). The results showed that cognitive biases behaved consistently across time from early to mid-adolescence, with Negative Bias, Positive Bias, and Attention Bias poly-bias scores emerging at both time points. Furthermore, we found partial support for the hypothesis regarding the stability of worry and poly-bias scores across time. The results indicated that Negative Bias, Positive Bias, and the tendency to worry remained stable from early to mid-adolescence, however the presence of an Attention Bias was not consistent across time. Finally, the hypotheses that poly-bias scores would predict levels of worry was partially supported. The current study found that Negative Bias in early adolescence predicted high worry in mid-adolescence. However, the reverse relationship was also significant, as high worry in early adolescence predicted Negative Bias in mid-adolescence. There was no evidence to suggest that a Positive Bias or Attention Bias in early adolescence caused worry in mid-adolescence.

The present study provides some support for the combined cognitive bias hypothesis (Hirsch et al., 2006) by demonstrating that interpretation and memory biases are interrelated cognitive processes in adolescents. The associations between attention, interpretation, and memory biases in mid-adolescence was consistent with the pattern of results observed in the same sample of adolescents when they were younger (see Chapter Three), which suggests that cognitive biases remain stable across time. Across time, Negative Bias and Positive Bias emerged as the strongest factors, followed by Attention Bias. However, one difference across time was that the factor structure of the PCA in early adolescence revealed a fourth component, termed an Attention Bias to Threat and comprised of angry and pain bias variables, which did not emerge at mid-adolescence. Perhaps as cognitive processes in adolescents develop over time, attention bias - including attention to positive stimuli - becomes more generalised. In line with the findings of the previous chapter, the attention bias variables were associated with one another, albeit to a small extent, however did not correlate with either the interpretation or memory bias variables. This suggests that interpretation and memory biases are more closely interrelated cognitive processes in adolescents.

A possible explanation for the lack of association between attention biases and interpretation or memory biases may be due to the poor split half reliability of the Dot-probe task in our current sample of adolescents (Kruijt, et al., 2016; Parsons et al., 2018), which may be measuring statistical noise and contributes to a large amount of unexplained variability. Some researchers have suggested that when conducting a PCA, variables that do not correlate with other variables should not be included in further analysis. To account for this, separate analysis at T1 and T2 including and excluding the attention bias variables in the PCA were conducted and showed an identical pattern of results (see Appendix F). Thus, even though the attention bias variables in our sample did not correlate with the interpretation or memory bias variables, we still included them in further analyses as our a-priori plan was to explore the relationship amongst all of these cognitive biases in light of the combined cognitive bias hypothesis. Whilst the results surrounding attention bias need to be interpreted with caution, the findings indicate that interpretation and memory biases are interrelated cognitive processes during early to mid-adolescence and combine to form Negative and Positive Biases. This suggests that adolescence is an important developmental period where certain cognitive biases begin to collectively work together and form habitual thought patterns.

The current findings are consistent with studies in adults investigating the combined cognitive bias hypothesis, which show that interpretation biases influence memory biases as adults tend to recall information according to their biased interpretation of ambiguous scenarios (Hertel & El-Messidi, 2006; Hertel et al., 2008; Salemink et al., 2010; Tran et al., 2011). In contrast, there are limited studies that have examined the combined cognitive bias hypothesis in adolescents. Klein and colleagues (2017) found that adolescents with high levels of self-reported anxiety and depression, showed stronger biases in both attention and interpretation compared to adolescents with low levels of self-reported anxiety and depression. Whilst Orchard and Reynolds (2018) showed that a combination of interpretation bias and self-evaluation bias was a stronger predictor of depression in adolescents than individual biases. The present study extends the literature by examining attention, interpretation, and memory biases simultaneously in adolescents with varying levels of worry and importantly, demonstrating how these cognitive processes develop over time.

The current study found that worry, Negative Bias, and Positive Bias remained stable cognitive processes over time. In all three structural models, the results consistently showed that worry was a stable trait during adolescence. These findings are in line with previous research that shows worry is a stable trait (Caes et al., 2015; Chorpita et al., 1997). The mean levels of worry at T1 and T2 were normally distributed and are in line with non-clinical studies in adolescents that use the PSWQ-C, suggesting that the results are generalizable to the population (Chorpita et al., 1997; Dugas et al., 2012; Fialko et al., 2012; Pestle et al., 2008). Furthermore, there was a smaller range and less variation in worry scores at T2 compared to T1, suggesting that worry is tightly clustered and becomes more consistent in adolescents over time. Moreover, Negative Bias and Positive Bias also remained stable from early to mid-adolescence. This suggests that negative and positive cognitive biases serve as important risk and protective mechanisms that may influence the development of worry in adolescents.

The present study found that Negative Bias in early adolescence predicted high levels of worry in mid-adolescence. Whilst, high levels of worry in early adolescence predicted Negative Bias in mid-adolescence. These findings suggest that Negative Bias plays an important role in the aetiology of worry and provides insight into the causal mechanisms underlying adolescent worry. It appears that the causal pathways between Negative Bias and worry during adolescence work in both directions, and is perhaps a reflection that the negative cycle of worrisome thoughts and negative cognitive biases have already begun to develop as habitual thought patterns by this age. These results are consistent with cognitive theories of anxiety in youth that emphasise the role of negative cognitive biases of threat related stimuli in the manifestation of anxiety. However, there was no evidence to suggest that Positive Bias or Attention Bias have a causal relationship with adolescent worry. The results showed that Positive Bias and Attention Bias in early adolescence did not predict levels of worry in mid-adolescence. This suggests that Negative Bias are cognitive processes that are more salient during mid-adolescence and become more consistent thought patterns that have an impact on worry over time.

A number of limitations of the present investigation should be noted. Firstly, although significant, the effect sizes were small. This statistical significance may be partially due to the high analytical power provided by the large sample size and further replication of the current findings in adolescents is needed to validate the results. Secondly, the findings related to attention bias may be compromised by the poor split half reliability issues with the Dot-probe task in our current sample of adolescents as well as group testing conditions, which may have interfered with adolescent's concentration levels to capture attention. Conclusions drawn regarding attention biases in the present sample should be interpreted with caution and further studies examining the reliability of the Dot-probe task in youth is needed. Although, given the large sample size and high statistical power calculated in the current study to detect a medium to large effect size, the results suggest that attention bias may not be as important as interpretation and memory biases for the development of worry from early to mid-adolescence.

Another limitation to the study is the use of cross-lagged panel models, which have been met with some criticism (Hertzog & Nesselroade, 1987; Rogosa, 1987; Selig & Little, 2012). The cross-lagged panel model was limited to two variables studied across time and it may be that measurement error or other factors are likely to influence the causal relationship between cognitive biases and worry. In the present study, we attempt to account for this variance by including covariates in the model and controlling for gender, school, and SES, which are variables related to worry. Including these covariates in the statistical analysis showed a good model fit, suggesting that it is important to consider the role of covariates when constructing structural equation models. Given that this was the first study to examine the development of cognitive biases and worry in the transition period from early to mid-adolescence, cross-lagged models provide useful insights into the causal pathways and stability of variables over time. Cross-lagged panel models have the potential to shed light on longitudinal associations between variables that can further our understanding of developmental processes in youth. However, further longitudinal research in adolescents over multiple time points, is needed to replicate and validate these findings.

The current study has many strengths that make a valuable contribution to the literature and extends our understanding of how normal worry develops from early to mid-adolescence. To the best of our knowledge, this was the first longitudinal study to investigate the development of cognitive biases and worry in a large sample of healthy adolescents. The longitudinal design allows examination of the cognitive mechanisms and pathways involved in the aetiology of adolescent worry. In addition, through structural equation modelling, the cross-lagged panel model enables the investigation of bi-directional effects to examine whether cognitive variables causally precede adolescent worry. Furthermore, the current study provides support for the combined cognitive bias hypothesis in an adolescent sample and advances our knowledge of the interrelationships amongst attention, interpretation, and memory biases and how these cognitive processes combine to influence worry across adolescence.

One clinical implication of the present study is that it provides preliminary evidence for potential cognitive mechanisms to target in early interventions for worry in healthy adolescents. The results suggest that Negative Bias, a combination of negative interpretations of ambiguous scenarios and negative memory bias, are mechanisms underlying the aetiology of worry in adolescents. Perhaps targeting a combination of these negative biases in early interventions for worry and teaching adolescents strategies on how to recognise and challenge maladaptive thoughts would be useful to incorporate into current programmes. In addition, the results suggest that targeting both Negative Bias and worry in early adolescence may reduce negative biases and levels of worry in mid-adolescence, and perhaps the most efficacious interventions would incorporate both of these cognitive processes.

An advantage to using the poly-bias approach is that it provides insight into the combination of negative biases that could potentially be targeted in early interventions for worry. However, the present study did not examine the causal relationship of individual biases with worry and it may be that negative interpretation or negative memory bias in isolation have a stronger causal relationship with worry. Future research is needed to investigate the predictive magnitude of poly-bias scores and whether a combination of cognitive biases are a better predictor of worry than individual biases alone. Nevertheless, the combined cognitive bias approach of using poly-bias scores, may reflect how these cognitive processes operate together during adolescence and provides a deeper understanding of the multiple cognitive biases that could potentially be targeted in early interventions.

Furthermore, disorder specific treatments for GAD have been extensively tested in adults, however studies in adolescents have lagged behind. A small number of studies have investigated the efficacy of GAD specific treatments in youth that target cognitive factors implicated in the aetiology and maintenance of pathological worry, with promising results (Holmes et al., 2014, 2015; Leger et al., 2003; Payne et al., 2011). The current study highlights the importance of cognitive biases as causal mechanisms underlying adolescent worry, which may have the potential to improve current interventions in youth.

The majority of research on child and adolescent worry to date has been correlational in design and further longitudinal and experimental studies would help illuminate our understanding of the causal pathways underlying adolescent worry. Future studies could examine how attention, interpretation, and memory biases develop over time in younger children when worry begins to emerge and become more engrained in middle childhood. This may provide early insights into when negative biases develop and cause the onset of high worry in children. In addition, longitudinal and experimental designs that examine the development of cognitive biases during adolescents into early adulthood would provide a deeper understanding of the risk and protective mechanisms involved in the trajectory of pathological worry. Moreover, future studies should aim to examine cognitive biases in combination, with growing evidence to suggest that these cognitive processes influence each other and may not operate in isolation. Adolescence is an important period for the development of worry (Copeland et al., 2014) and further research examining key transition periods in adolescents and the influence of cognitive development on worry may help prevent the onset of pathological worry or anxiety.

Finally, it is important for future studies to examine worry within a developmental framework to better understand the cognitive, emotional, social, and age-related changes that may influence the aetiology of worry in youth. So far, we have shown that cognitive biases, in particular a combination of negative biases, play a role in the aetiology of worry. Future studies investigating the role of executive functions such as attentional control and working memory in the development of worry, would provide a deeper understanding of how higher order cognitive processes interact with more involuntary cognitive biases. Studies examining this interaction, would support Hirsch and Matthews' cognitive model of pathological worry and demonstrate that cognitive processes in youth operate in similar ways to adult pathological worry.

Increasing our understanding of the development of worry in healthy adolescents is essential to identifying the risk mechanisms that lead to excessive worries observed in GAD, as well as the protective factors that may prevent some adolescents from emotional vulnerability. Given the profound impact worry has on daily functioning and mental health outcomes, adolescence is an important developmental period where certain cognitive processes may be more malleable to change. Thus, further investigation of the role of cognitive mechanisms such as cognitive biases and executive functions in adolescent worry is imperative to improving current treatments and interventions for worry in youth and a priority for building emotionally healthy adolescents.

Chapter 5

5

The Role of Executive Functions in Adolescent Worry

A growing body of research in the youth and adult literature has shown that impaired executive functions are associated with high worry and anxiety. This study investigated whether deficits in attentional control and working memory were associated with high worry in adolescents. In addition, the study examined whether these executive functions moderated the association between cognitive biases and worry in adolescents, as proposed in Hirsch and Matthews' cognitive model of pathological worry in adults (2012). Data was drawn from time point two of the CogBias Longitudinal study. The results showed that poor attentional control and low working memory capacity were not associated with high worry in adolescents. Moreover, attentional control and working memory did not moderate the relationship between cognitive biases and worry in adolescents. In contrast to the previous literature, the findings suggest that executive functions are not associated with worry and do not interact with cognitive biases in our sample of adolescents.

5.1. Introduction

In previous chapters, we highlighted the importance of cognitive biases as mechanisms underlying worry in adolescents and provided empirical support for the first building block of Hirsch and Matthews' cognitive model of pathological worry in adolescents (2012). The second building block in the model proposes that deficits in executive functions are cognitive processes involved in the aetiology of worry. According to the model, pathological worry arises due to the interaction between cognitive biases, which are relatively involuntary processes that occur without awareness, and the voluntary, goal directed processes of executive functions. In this chapter, we investigate whether executive functions play a role in the manifestation of worry in adolescents. Furthermore, to test the applicability of Hirsch and Matthews' model of pathological worry (2012) in adolescents, we examine whether executive functions moderates the relationship between cognitive biases and worry. This would provide preliminary support for the cognitive model of child and adolescent worry we proposed in Chapter Two.

Executive functions, also referred to as executive control or cognitive control, are a collection of mental processes that regulate thoughts and behaviours (Friedman et al., 2008; Friedman & Miyake, 2017). It is widely accepted in the literature that there are three core executive functions, which include; inhibition, working memory, and cognitive flexibility (Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). These higher order cognitive processes are responsible for the ability to control impulses, resist temptations, concentrate and stay focused, problem-solve, establish goals, plan, and reason (Diamond, 2013). The use of executive functions involves effortful control processes linked to the prefrontal cortex (Beaty, Benedek, Silvia, & Schacter, 2016; Miller & Cohen, 2001; Niendam et al., 2012), that are distinct from the involuntary processes of cognitive biases, which are associated with more primitive regions and networks in the brain (Menon, 2011; Palmer, Crewther, & Carey, 2015; Rayner, Jackson, & Wilson, 2016). Behavioural and neurological studies have shown that there are considerable individual differences in the ability to self-regulate and manage thoughts, emotions, and actions during goal directed behaviour (Friedman & Miyake, 2017; Rueda, Posner, & Rothbart, 2011). These executive functions are important cognitive skills essential for development, academic success, age-related decline as well as physical and mental health outcomes (Mischel et al., 2011; Moffit et al., 2011).

Research in the adult literature has shown that impaired executive functions are associated with worry and anxiety (Derryberry & Reed, 2002; Eysenck, 1979; Eysenck & Calvo, 1992; Moran, 2016). In particular, experimental studies in adults demonstrate that high worry and anxiety leads to reduced working memory capacity and deficits in attentional control (Fox et al., 2015; Hayes et al., 2008; Leigh & Hirsch, 2011; Rapee, 1993; Sari, Koster, & Derakshan, 2016; Stefanopoulou, Hirsch, Hayes, Adlam, & Coker, 2014). Working memory involves the ability to store information in mind and mentally manipulate it to perform certain tasks such as reasoning, decision making, and planning (Baddeley & Hitch, 1994). Another core executive function, attentional control, also referred to as inhibitory control, is the capacity to selectively focus on information based on our goals and intentions, whilst ignoring and suppressing attention to other distracting stimuli (Posner & DiGirolamo, 1998). The attentional control theory (ACT; Eysenck et al., 2007), for instance, proposes that worry consumes the limited cognitive resources available in the central executive system, making it more difficult to shift attention away from intrusive negative thoughts and reducing working memory capacity to perform tasks. In other words, it is hypothesised that individuals with high worry or anxiety find it difficult to ignore distracting thoughts and maintain attentional focus, thus taking up attentional resources and impairing task efficiency (Hirsch & Matthews, 2012).

In contrast to a relatively advanced understanding of the cognitive mechanisms underlying worry in adults, research on the relationship between executive functions and adolescent worry has lagged behind. As reviewed in Chapter Two, there is some evidence to suggest that reduced working memory, poor attentional control, and deficits in emotion regulation are executive functions associated with high worry and GAD in adolescents. For example, Trezise and Reeve (2014, 2016) used a novel Algebraic Working Memory task to investigate the effect of worry on working memory in relation to academic performance in adolescent girls aged 14 years old. The study found that high worry and low working memory were associated with poor problem solving performance, whilst low worry and high working memory were related to high problem solving performance (Trezise & Reeve, 2014). Similarly, a study by Owens and colleagues (2012) found that high worry and working memory, as measured by the digit span and spatial span tasks, mediated the relationship between anxiety, depression, and academic performance in early adolescents aged 12 to 13 years old. Together, these studies suggest that working memory is an important cognitive process underlying adolescent worry and may be a mediating factor in the relationship between negative affect and academic performance.

Furthermore, the systematic review in Chapter Two found that poor attentional control, was associated with high worry and anxiety in adolescents (Sportel et al., 2011; Verstraeten et al., 2011) A study by Sportel and colleagues (2009) demonstrated that attentional control, as measured by means of a questionnaire, moderated the association between behavioural inhibition and symptoms of worry in adolescents. Moreover, adolescents with low attentional control combined with high behavioural inhibition reported the highest levels of generalized anxiety symptoms. In contrast, a high degree of attentional control combined with reduced behavioural inhibition was associated with low symptoms of generalized anxiety disorder. Similarly, another study showed that attentional control was uniquely associated with anxiety symptoms and not depression in children and adolescents aged 9 to 13 years old (Verstraeten et al., 2011). These studies suggest that attentional control plays an important role in adolescent worry and anxiety, which may act as a self-regulatory moderating variable between worry and behavioural temperaments, however research in adolescence remains scarce.

Broadly, studies in adolescents indicate that worry interferes with working memory capacity and attentional control, which provides support for the ACT (Eysenck et al., 2007) and the cognitive model of pathological worry (Hirsch & Matthews, 2012). However, studies in youth often pool together child and adolescent age groups making it difficult to disentangle age related effects and the specific role executive functions may play across the different stages of development. We proposed in our cognitive model of child and adolescent worry in Chapter Two, that executive functions are cognitive processes that are influenced by various age related factors such as cognitive, social, and emotional development. Thus, future studies examining the interrelationships between worry, working memory, and attentional control either longitudinally to examine developmental differences or during a narrow age range in adolescence may provide important insights into the cognitive nature of worry.

We suggest in Chapter Two, that adult conceptualisations of worry may not be suitable to understanding adolescent worry given the different cognitive and developmental stages (Cartwright-Hatton et al., 2011). For instance, a developmental perspective of executive functions suggests that infants have the ability to shift their attention at an early age as demonstrated through soothing and distraction techniques (Harman, Rothbart, & Posner, 1997). However, self-regulated attentional control does not develop until around two years of age (Ursache, Blair, Stifter, & Voegtline, 2013). Research shows that executive functions develop rapidly from infancy through to early childhood, with regulatory processes believed to mature around the age of 12 and then continue to develop until young adulthood

(Anderson, 2002). According to self-reports, anxious children appear to be less skilled in flexible control of attention, an important element in the ability to regulate emotions (Lonigan et al., 2004). The development of specific functions, such as attentional control, information-processing, and problem solving are thought to stabilise between the age of 12 and 15 years, which suggests that patterns of executive functions during this period may remain constant into adulthood (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001). Thus, adolescence represents a crucial developmental period for the aetiology of worry and further research investigating the role of attention control and working memory would advance our current knowledge and provide valuable insights into the worry process (Gramszlo & Woodruff-Borden, 2015).

The present study investigated whether the executive functions of attentional control and working memory were associated with worry in adolescents. Furthermore, to test our cognitive model proposed in Chapter Two, the present study examined whether executive functions moderated the effect between cognitive biases and worry. The role of executive functions in adolescent worry was assessed at time point 2 of the CogBias Longitudinal study when adolescents were aged 13 to 16 years old. In line with the combined cognitive bias hypothesis (Hirsch et al., 2006), we assessed cognitive biases using poly-bias scores, a score comprised of a combination of interpretation, memory, and attention biases, to show that cognitive biases may not operate in isolation, but rather interact and influence each other during adolescence.

Consistent with the literature, we hypothesised that deficits in attentional control and poor working memory capacity would be associated with high worry in adolescents. Secondly, we predicted that attentional control and working memory would moderate the relationship between poly-bias scores and worry in adolescents (see Figure 5.1). In Chapter Four, we demonstrated that having a Negative Bias in early adolescence was a strong predictor of worry at mid-adolescence, and also that worry in early adolescence predicted a Negative Bias in mid-adolescence. Thus, we hypothesised that attentional control and working memory capacity would moderate the relationship between Negative Bias and worry in adolescents. That is, as levels of attentional control and working memory decrease, the relationship between Negative Bias and worry will increase. Conversely, as levels of attentional control and working memory increase, the relationship between Negative Bias and worry will decrease. As the Positive Bias and Attention Bias poly-bias scores did not predict worry across time in Chapter Four, we do not expect executive functions to moderate the relationship between cognitive biases and adolescent worry. However, we conducted the analysis for exploratory purposes as our a-priori plan was to examine the relationship amongst all cognitive biases in the CogBias Longitudinal study.

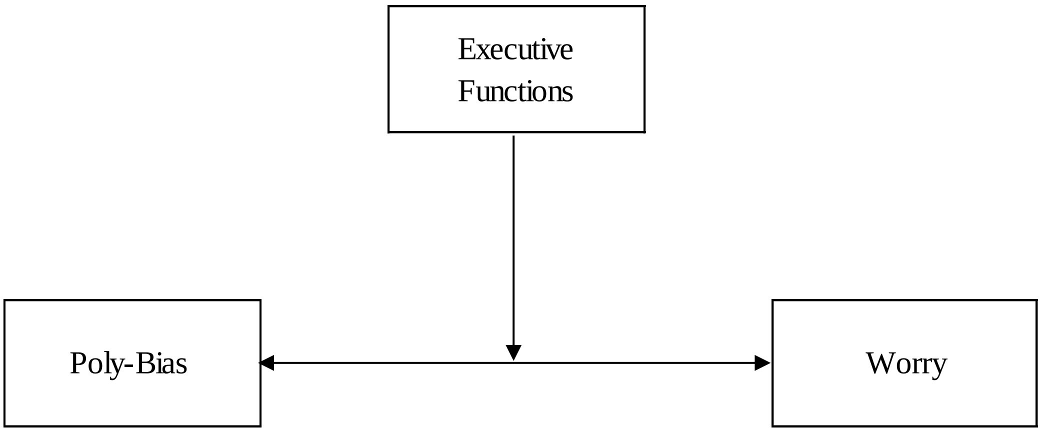

Figure 5.1. Model of executive functions moderating the relationship between Poly-Bias scores and Worry

5.2. Method

Participants

Participants (*N* = 450) were drawn from time point 2 (T2) of the CogBias Longitudinal study, which was approximately 12 to 18 months after data collection at time point 1 (T1). The sample comprised of adolescents aged 13 to16 years old (*M* = 14.55, *SD* = .63) with 56% females. Participants were identical to the sample described in Chapter Four. For a detailed description of the study design, procedure, demographic information, and sample characteristics refer to Chapter Four and the protocol paper (Booth, Songco et al., 2017).

Procedure

Testing sessions were conducted in group conditions in computer labs at participating schools or at the Department of Experimental Psychology, University of Oxford. The testing procedure was identical to that outlined in Chapter Four, where participants completed questionnaires and cognitive tasks for two hours under exam conditions, with a short break after the first hour.

Measures

In Chapter Five, only data from the following cognitive tasks and self-report measures from T2 of the CogBias Longitudinal study were analysed, which were relevant for the current study's research questions.

Self-report measures

Demographic questionnaire. Parent self-report on a demographic questionnaire assessed information such as adolescent's age, gender, ethnicity, household size, parent's education and occupation. Consistent with Chapters Three and Four, demographic information related to SES, as well as school and gender were controlled for in the analyses to account for confounding effects. The school variable encapsulates the different schools, year levels, time of year that the testing sessions were conducted, and the various time lags between the testing sessions in schools.

Worry. The Penn State Worry Questionnaire for Children (PSWQ-C; Chorpita et al., 1997) is a 14 item self-report measure used to assess the tendency to worry in children aged 6 to 18 years old (see Appendix B). Examples of items include "My worries really bother me" and "I know I shouldn't worry, but I just can't help it." Each item was rated on a 4-point Likert scale (0 = Never true to 3 = Always true) and a Worry Total Score was calculated by summing the items. Higher scores on the PSWQ-C indicate more frequent and uncontrollable worries. In adolescent samples, the PSWQ-C has excellent internal consistency, good convergent and discriminant validity, and test-retest reliability in clinical and non-clinical samples (Chorpita et al., 1997; Pestle et al., 2008). The internal consistency on the PSWQ-C for the current study was good ($\alpha = .81$).

Cognitive tasks

Working memory. The Corsi Block Tapping Task, forwards and backwards span, was used to measure visuospatial working memory capacity (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000; Kessels, van den Berg, Ruis, & Brands, 2008). Participants were presented with a screen that consisted of nine blue squares and in each trial the squares flashed in yellow according to a pre-fixed sequence (see Appendix G). The flashing time of the squares (from blue to yellow) was set to 500ms and the interblock interval (ITI) was set to 1000ms. In the forwards span, participants were instructed to remember and recall a visual pattern of sequences in the correct order that they were presented by clicking on the correct squares on the screen. Following this, the backwards span was administered where participants had to recall the pattern of sequences in the reverse order.

The sequence length started at level two (i.e. two squares) and increased up to level nine for the forwards span and up to level eight for the backwards span. There were two trials per length, with a total of 16 trials in the forwards span and 14 trials in the backwards span. Participants were given two chances to correctly recall each sequence length in forwards order or in reversed fashion. If one of the sequences was entered correctly, the next sequence began. Forwards and backwards span was calculated as the longest sequence that was remembered correctly. The Corsi Block Tapping task has been widely used in research and clinical settings as a measure of visuospatial working memory and has shown good validity and reliability across different ages (Farrell, Pagulayan, Busch, Medina, Bartok, & Krikorian, 2006; Orsini, Schiappa, Chiacchio, & Grossi, 1982; Orsini et al., 1987). In addition, the Corsi Block Tapping task has been validated in various patients groups with Alzheimer's disease, stroke, traumatic brain injury, dementia, and psychiatric disorders (Kessel et al., 2000, 2008).

Attentional control. The Flanker task (Eriksen, 1995) was used to assess an aspect of attentional control known as response inhibition. Participants were instructed to respond to the direction of a target fish in the middle of the screen, whilst ignoring two fish on either side of the target fish (see Appendix H). There were 116 trials which were randomly and equally likely to be congruent trials (when the flanker fish points in the same direction as the target) or incongruent trials (when the flanker fish points in the opposite direction, causing interference). There were four trial types; target (left) congruent, target (right) congruent, target (left) incongruent, and target (right) incongruent. The stimuli were yellow fish with a faint black arrow embedded in the image (150 x 230 pixels) and are presented approximately 1 degree of visual angle apart on a white background. Participants completed ten practice trials with only the target fish and ten practice trials with the flanker fish, which were not analysed. Responses were made using the left/right strict inequality symbols ("<" and ">") and participants were instructed to keep their index fingers on the response keys throughout the task so that they could respond as fast as possible. Participants were also instructed not to make any mistakes and an error message is displayed when an incorrect response is made ("Wrong response") or when responses were slower than 2500ms ("Too slow"). Error feedback is displayed for 1000ms and the ITI is 1250ms. A short rest period is given halfway through the task and a countdown clock is shown for 30000ms. Difference in RT between congruent and incongruent trials reflects response inhibition (high numbers reflecting strong interference).

Poly-bias scores. Poly-bias scores are comprised of a combination of attention, interpretation, and memory bias variables. In line with the combined cognitive bias hypothesis (Hirsch et al., 2006), poly-bias scores recognise that multiple cognitive biases may interact and influence each other at various stages of the cognitive system to maintain and exacerbate psychopathology in adolescents. To derive poly-bias scores, a principle components analysis of the attention, interpretation, and memory bias variables was conducted at time point 1 and time point 2 of the CogBias Longitudinal study (see Chapters

Three and Four). The results showed a similar factor structure across time from early to mid-adolescence, where the poly-bias scores of Negative Bias, Positive Bias, and Attention Bias emerged as consistent components. Negative Bias consisted of high factor loadings of the negative interpretation bias variables of social and non-social scenarios as well as negative memory bias. In addition, Positive Bias comprised of high factor loadings of the positive social and non-social interpretation bias variables and positive memory bias. Whilst, Attention Bias variables of an angry, pain, and happy bias loaded onto an Attention Bias component. Factor scores for each component were calculated by summing the weighted betas of the relevant items to create three poly-bias scores; Negative Bias, Positive Bias, and Attention Bias. The factor scores derived at time point 2 of the CogBias Longitudinal study were used in the analysis of the present study (see Chapter Four for details).

Data Analysis Plan

Hierarchical Multiple Regression

To examine whether attentional control and working memory were associated with worry in adolescents, a hierarchical multiple regression was conducted using attentional control (Flanker task) and working memory (Corsi Block Tapping Task) as the independent variables and the tendency to worry (PSWQ-C) as the outcome variable. To investigate the hypothesis that attentional control or working memory would moderate the relationship between cognitive biases and worry, three separate hierarchical multiple regressions for each of the poly-bias scores at T2 (Negative Bias, Positive Bias, and Attention Bias) were performed. Poly-bias scores were entered as the independent variable, worry was included as the outcome variable, and attentional control and working memory were entered as the moderating variables.

In the first step of each of the hierarchical multiple regressions, the demographic variables of gender, school, and SES were entered in order to control for confounding variables. In the second step of the three models, poly-bias score, attentional control and working memory were included using the enter selection method. The interaction terms were then added in the third step of the hierarchical multiple regression. To avoid potentially problematic high multicollinearity with the interaction term, the variables were centred and interaction terms were created based on these centred variables (Aiken & West, 1991). In addition, preliminary analyses were conducted to ensure that there were no violations of the assumptions of normality, linearity, multi-collinearity, and homoscedasticity.

Missing data

There was no missing data for participants on the PSWQ-C and the Flanker task (N = 450). In the Flanker task, error trials and trials < 200ms or > 2500ms were not analysed, as well as trials that were three *SD's* from each participant mean RT for each trial type (1% of trials), to remove trials reflecting pre-emptive responses or delayed responses, respectively. Due to a technical fault, data was missing for one participant on the backwards Corsi Block Tapping task (N = 449) and two participant's data were missing on the forwards Corsi Block Tapping task (N = 448). In addition, SES data was missing for 19 participants. The subsequent analyses were performed excluding participants with missing data.

5.3. Results

Descriptive Statistics at Time Point 2

Descriptive statistics were identical to the sample described in Chapter Four. In relation to executive functions, the mean level of attentional control in adolescents was M =

26.63 (*SD* = 22.38), with males showing significantly higher levels of attentional control (*M* = 29.10, *SD* = 24.29) compared to females (*M* = 24.65, *SD* = 20.58; *t*(448) = 2.10, *p* =.036; *d* = 0.20). In addition, the mean level of working memory capacity on the forwards span was *M* = 57.12 (*SD* = 21.29), with no gender differences found between males and females *t*(446) = .43, *p* =.668; *d* = 0.02). Similarly, the mean level of working memory capacity on the backwards span was *M* = 49.38 (*SD* = 16.55), with no gender differences emerging between males and females *t*(447) = -1.04, *p* = .298; *d* = 0.10). Table 5.1. presents the correlations amongst all bivariate relationships between worry, attentional control, working memory, Negative Bias, Positive Bias, and Attention Bias, with associations all in the expected direction. For a detailed description of the sample characteristics see the Results section of Chapter Four.

Table 5.1

Correlations of Worry with Executive Function Variables and Poly-bias Scores

Variable	1	2	3	4	5	6
1. Worry						
2. Attentional Control	.01					
3. Working Memory Forwards Span	-.04	-.14**				
4. Working Memory Backwards Span	.02	-.12*	.23**			
5. Negative Bias	.57**	-.05	.02	-.01		
6. Positive Bias	-.25**	-.02	.03	.11*	-.22**	
7. Attention Bias	-.02	-.06	-.03	-.04	-.01	-.02

Note. *p < .05 **p <. 01

Hierarchical Multiple Regression

Executive functions and worry

The results of the hierarchical multiple regression of executive functions on outcomes of worry, controlling for gender, school, and SES are presented in Table 5.2. The analysis revealed no significant relationship between worry and attentional control, working memory forwards span, and working memory backwards span. In the first step of the hierarchical multiple regression, gender, school, and SES made a significant contribution to the variance in worry scores ($F(3, 427) = 6.33$, $p < .001$) and explained 4% of the variance. After entry of the executive function variables at the second step of the analysis, the model was not significant ($F(3, 424) = .32$, $p = .813$). We also tested for a gender x executive functions interaction, however there were no significant interactions of gender differences between worry and attentional control or working memory.

Table 5.2

Summary of Hierarchical Multiple Regression for Executive Functions and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.04				
Gender		2.84	.71	.20***	4.02
School		-.38	.28	-.07	-1.35
SES		.21	.15	.07	1.43
Step 2	.00				
Gender		2.89	.72	.20	4.04
School		-.37	.28	-.06	-1.30
SES		.21	.15	.07	1.44
Attentional Control		.01	.02	.04	-.48
Working Memory Forwards Span		-.01	.02	-.02	.42
Working Memory Backwards Span		.01	.02	.02	.75

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

Moderation analysis of executive functions, negative bias, and worry

To test the hypothesis that attentional control and working memory moderates the relationship between Negative Bias and worry, a hierarchical multiple regression analysis was conducted controlling for gender, school, and SES (see Table 5.3). In the first step of the hierarchical multiple regression, the demographic variables of gender, school, and SES were included. These variables accounted for a significant amount of variance in worry scores ($F(3, 424) = 6.48$, $p < .001$) and explained 4% of the variance. At the next step, Negative Bias and the executive function variables were added to the regression model, which accounted for a significant proportion of the variance in worry scores ($\Delta R^2 = .29$, $F(4, 420) = 45.58$, $p < .001$). Only Negative Bias made a significant contribution to the variance of worry ($\beta = .57$). In the third step of the model, the interaction term between executive functions and Negative Bias was added to the model, however there were no significant interactions between Negative Bias and attentional control, working memory forwards span or working memory backwards span in predicting outcomes of worry ($F(3, 417) = .361$, $p = .781$).

Table 5.3

Summary of Hierarchical Multiple Regression for the Moderation of Executive Functions on Negative Bias and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1	.04***				
Gender		2.89	.71	.20***	4.08
School		.21	.15	.07	1.44
SES		-.38	.28	-.07	-1.35
Step 2	.29**				
Gender		.16	.63	.01	.25
School		.01	.12	.00	.09
SES		-.42	.24	-.07	-1.79
Negative Bias		4.12	.31	.57***	13.46
Attentional Control		.01	.01	.04	.86
Working Memory Forwards Span		-.01	.01	-.03	-.83
Working Memory Backwards Span		.02	.02	.04	.94
Step 3	.00				
Gender		.12	.63	.01	.19
School		.01	.12	.00	.04
SES		-.42	.24	-.07	-1.77
Negative Bias		4.13	.31	.57	13.44
Attentional Control		.01	.01	.04	.92
Working Memory Forwards Span		-.01	.01	-.03	-.81
Working Memory Backwards Span		.02	.02	.04	.89
NegBias x Attentional Control		-.01	.01	-.03	-.67
NegBias x Working Memory Forwards		-.01	.02	-.00	-.07
NegBias x Working Memory Backwards		.01	.02	.03	.65

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

Moderation analysis of executive functions, positive bias, and worry

To investigate whether the association between Positive Bias and worry depends on levels of attentional control and working memory, a hierarchical multiple regression analysis was conducted controlling for gender, school, and SES (see Table 5.4). In the first step of the hierarchical multiple regression, the demographic variables of gender, school, and SES were included. These variables accounted for a significant amount of variance in worry scores ($F(3, 424) = 6.48$, $p < .001$) and explained 4% of the variance. At the next step, Positive Bias and the executive function variables were added to the regression model, which accounted for a significant proportion of the variance in worry scores ($\Delta R^2 = .05$, $F(4, 420) = 6.26$, $p < .001$). Only Positive Bias made a significant contribution to the variance of worry (β = -.24). In the third step, the interaction term between executive functions and Positive Bias was added to the regression model, however there were no significant interactions between Positive Bias with attentional control, working memory forwards span or working memory backwards span in predicting outcomes of worry ($\Delta R^2 = .01$, $F(3, 417) = 1.25$, $p = .292$).

Table 5.4

Summary of Hierarchical Multiple Regression for the Moderation of Executive Functions on Positive Bias and Worry (PSWQ-C)

Variable	ΔR²	*b*	SE *b*	β	t
Step 1	.04***				
Gender		2.89	.71	.20**	4.08
School		.21	.15	.07	1.44
SES		-.38	.28	-.07	-1.35
Step 2	.05***				
Gender		2.58	.70	.18***	3.68
School		.27	.14	.09	1.90
SES		-.16	.28	-.03	-.57
Positive Bias		-1.76	.36	-.24***	-4.93
Attentional Control		.01	.02	.03	.58
Working Memory Forwards Span		-.01	.02	-.02	-.45
Working Memory Backwards Span		.02	.02	.04	.88
Step 3	.01				
Gender		2.55	.70	.18***	3.63
School		.25	.14	.09	1.76
SES		-.17	.28	-.03	-.60
Positive Bias		-1.71	.37	-.23***	-4.69
Attentional Control		.01	.02	.04	.70
Working Memory Forwards Span		-.01	.02	-.02	-.31
Working Memory Backwards Span		.01	.02	.03	.66
PosBias x Attentional Control		.02	.01	.07	1.18
PosBias x Working Memory Forwards		.01	.02	.02	.44
PosBias x Working Memory Backwards		.04	.02	.09	1.70

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

Moderation analysis of executive functions, attention bias, and worry

To test whether attentional control and working memory moderates the relationship between Attention Bias and worry, a hierarchical multiple regression analysis was conducted controlling for gender, school, and SES (see Table 5.5). In the first step of the hierarchical multiple regression, the demographic variables of gender, school, and SES were included. These variables accounted for a significant amount of variance in worry scores ($F(3, 422) = 6.59$, $p <.001$) and explained 4% of the variance. At the next step, Attention Bias and the executive function variables were added to the regression model, which did not make a significant contribution to the amount of variance in worry scores ($F(4,418) = .221$, $p < .001$). In the third step, the interaction term between executive functions and Attention Bias was included in the regression model, however there were no significant interactions between Attention Bias with attentional control, working memory forwards span or working memory backwards span in predicting outcomes of worry ($F(3, 415) = .551$, $p =.648$).

Table 5.5

Summary of Hierarchical Multiple Regression for the Moderation of Executive Functions on Attention Bias and Worry (PSWQ-C)

Variable	ΔR^2	*b*	SE *b*	β	t
Step 1					
Gender	.04***	2.94	.71	.21***	4.13
School		.22	.15	.07	1.49
SES		-.37	.28	-.06	-1.32
Step 2	.00				
Gender		3.01	.73	.21***	4.15
School		.22	.15	.07	1.46
SES		-.36	.28	-.06	-1.27
Attention Bias		-.20	.34	-.03	-.57
Attentional Control		.01	.02	.02	.42
Working Memory Forwards Span		-.01	.02	-.02	-.38
Working Memory Backwards Span		.01	.02	.03	.51
Step 3	.00				
Gender		3.02	.73	.21***	4.15
School		.22	.15	.08	1.51
SES		-.36	.29	-.06	-1.26
Attention Bias		-.11	.35	-.02	-.31
Attentional Control		.01	.02	.02	.42
Working Memory Forwards Span		-.01	.02	-.02	-.33
Working Memory Backwards Span		.01	.02	.02	.49
AttenBias x Attentional Control		-.01	.01	-.03	-.52
AttenBias x Working Memory Forwards		.02	.02	.05	1.01
AttenBias x Working Memory Backwards		-.02	.02	-.04	-.73

Note. PSWQ-C = Penn State Worry Questionnaire - Child version

[a] *p < .05 ** p< .01 ***p < .001

5.4. Discussion

The present study investigated whether attentional control and working memory were associated with worry in adolescents. Contrary to our predictions, poor attentional control and low working memory capacity were not associated with high worry in this sample of adolescents. Furthermore, attentional control and working memory did not moderate the influence of cognitive biases on worry in the sample. Surprisingly, these results are not consistent with the previous literature and they suggest that executive functions may not play a role in the development of adolescent worry in the CogBias sample.

In contrast to previous studies in adolescents (Owens et al., 2012; Sportel et al., 2011; Trezise & Reeve, 2014, 2016; Verstraeten et al., 2011), low levels of attentional control and working memory capacity were not associated with high worry. One possible reason for this may relate to the reliability of tasks used to measure executive functions in the current study, which may be tapping into different aspects of cognitive processing. To illustrate, there has been extensive debate and concern amongst researchers regarding the unity and diversity of the cognitive tasks used to assess executive functions and uncertainty as to which components of executive functions are assessed by each task (Diamond, 2013; Miyake et al., 2000). For instance, several studies have shown that tasks measuring executive functions do not correlate well due to low reliability, different strategy use amongst individuals, and lack of task purity (Burgess, 1997; Friedman & Miyake, 2017; Shallice & Burgess, 1996; Stuss & Alexander, 2000).

The present study used the Flanker task (Eriksen, 1995) as a measure of attentional control, which differs from previous studies that used questionnaire measures (Sportel et al., 2011; Verstraeten et al., 2011). This may account for the inconsistent findings as the use of cognitive tasks to measure executive control processes are based on reaction times, which may assess different aspects of inhibitory control compared to questionnaires measures. Similarly, working memory was measured in the current study using the Corsi Block Tapping Task (Kessels et al., 2000, 2008), which assesses visuospatial working memory capacity. However, previous studies assessing worry and working memory in adolescents have used various spatial span tasks (Owens et al., 2012; Trezise & Reeve, 2014, 2016), which may capture different aspects of working memory capacity (Baddeley & Hitch, 1994). It is clear that tasks measuring executive functions often involve complex cognitive processes that make it challenging to target specific cognitive abilities (Friedman & Miyake, 2017; Miyake et al., 2000). Thus, task choice in executive function research is vital and better reliability and consistency amongst studies that measure certain aspects of executive functions is needed in order to compare effects.

The present study found limited support for the second building block of Hirsch and Matthews' cognitive model of pathological worry (2012) in adolescents regarding the role of executive functions in worry. In line with Hirsch and Matthews' cognitive model, we proposed in Chapter Two in our cognitive model of child and adolescent worry that executive control processes would moderate the effect between cognitive biases and worry and act as a protective factor that would reduce the intrusive nature of worry. However, in the current study we found no evidence that attentional control and working memory moderated the relationship between cognitive biases and worry in adolescents. One possible reason for this is that during childhood and adolescence, perhaps higher order voluntary processes in the executive system work more closely together with lower level involuntary cognitive biases, which may only begin to separate and become more distinct in young adulthood. A number of studies have shown that the prefrontal cortex is still developing during adolescence and neutral networks are particularly malleable (Fuhrmann et al., 2015; Steinberg, 2014). Furthermore, some research indicates that cognitive processes such as attentional control and cognitive biases only begin to stabilise during early to mid-adolescence (Anderson, 2001; Anderson et al., 2002). In the current study adolescents were aged 13 to 16 and it could be that these cognitive processes are still developing at this age. Therefore an interaction between cognitive biases and executive functions in relation to habitual thought patterns of worry may only begin to emerge in older adolescents and young adulthood as the brain matures.

Moreover, another potential confound when examining the relationship between executive functions and cognitive biases in adolescents are issues surrounding task purity of executive functions. As noted by several researchers (Friedman & Miyake, 2017), assessing executive functions can be problematic due to the complex organisation of cognitive abilities in the executive system. Executive function tasks often involve high-level voluntary control processes whilst inhibiting lower-level involuntary processes and thus, when measuring the executive function of interest, tasks may also be tapping into other non-executive processes that could influence performance. Hence, in the current study as executive functions and cognitive biases may be working closely together, perhaps executive functions tasks are not reliable in terms of capturing these distinct cognitive abilities in youth.

The present study has a number of strengths and limitations that need to be addressed. One limitation is the use of cognitive tasks in correlational research. A recent study examining the test-retest reliability of commonly used executive function measures, including the Flanker task, demonstrated that cognitive tasks in correlational research are often sub-optimal and should be interpreted with caution given the low reliability in detecting individual differences (Hedge, Powell, & Sumner, 2018). In addition, measuring reaction time in the Flanker task may have been susceptible to similar reliability issues with the Dot-probe task highlighted in pervious chapters. For instance, group testing sessions in the CogBias Longitudinal study may have contributed to the lack of attention and concentration amongst adolescents whilst performing the Flanker task and perhaps compromised the reliability of the task. Furthermore, the low reliability of executive function tasks, in particular in children and adolescents, and the use of various measures capturing different aspects of executive functions may contribute to inconsistent findings in the literature. Whilst cognitive tasks may provide a more implicit measure of cognitive processes, there is surprisingly low reliability of these tasks considering their frequent use in experimental paradigms across cognitive neuroscience and psychology (Hahn et al., 2011; Lebel & Paunonen, 2011; Ross, Richler, & Gauthier, 2015).

Another limitation is that the present study was correlational in design. Adult studies examining the impact of worry on executive functions have implemented experimental paradigms and worry inductions that allow investigation of causal effects (Fox et al., 2015; Hayes et al., 2008; Leigh & Hirsch, 2011; Rapee, 1993; Sari et al., 2016; Stefanopoulou et al., 2014). These studies have contributed to a better understanding of how the worry process interferes with attentional control and working memory capacity in adults. In contrast to the adult literature, research examining worry in adolescents has typically been correlational in design with only one study to date implementing a worry induction paradigm to examine the nature of worry in adolescence (Frala et al., 2014).

Whilst there are limitations to the present study, there are also a number of strengths. To the best of our knowledge, this was the first study to examine the interaction between executive functions and a combination of cognitive biases, termed poly-bias scores, in a large sample of adolescents with varying levels of worry. Previous research on these cognitive processes have been studied in smaller samples and despite the non-significant results and small effect sizes of the current study, the large sample size and high power allows us to make stronger inferences regarding the results. In addition, there are few studies in the youth literature that have examined executive functions and cognitive biases simultaneously and within an adolescent population. Studies often combine child and adolescent age groups, which can be problematic given the rapid changes and the various developmental stages attained from childhood to adolescents. The present study extends the current literature on research examining executive functions that focus solely on adolescent populations, however further research is needed.

Furthermore, the current study was the first to investigate the interaction between cognitive biases and executive functions in the process of adolescent worry, as proposed in Hirsch and Matthews' cognitive model of pathological worry (2012). The results do not support the applicability of Hirsch and Matthews' model in adolescence and suggest that attentional control and working memory may not play a role in adolescent worry at this age, and executive functions do not interact with cognitive biases in the process of worry. Perhaps these cognitive processes are more interlinked during adolescence and become more distinct throughout later stages of development. As proposed in our cognitive model of child and adolescent worry, factors such as age, cognitive, social, and emotional development may have a major impact on how cognitive biases and executive functions operate during worry. However, there is limited empirical research to date that has addressed this and future studies incorporating a developmental framework to understand the cognitive processes underlying adolescent worry is crucial, as adult models of pathological worry may not be fully applicable to children and adolescents (Cartwright-Hatton et al., 2011).

Further research investigating the role of executive functions in adolescent worry is needed to better understand the aetiology of worry and the cognitive mechanisms underlying the manifestation of repetitive and intrusive negative thoughts. Future studies should aim to use reliable and consistent cognitive tasks that target similar aspects of executive control processes, in order to advance our knowledge on the specific elements of executive functions that are involved in the worry process in youth. In addition, studies should aim to use a developmental approach when investigating adolescent worry to acknowledge that cognitive processes may not operate the same way in youth as they would during adult worry. Finally, experimental and longitudinal designs are lacking in child and adolescent worry research. Therefore, the use of experimental and longitudinal studies to assess the development of worry and executive functions in adolescents would provide greater insight into the causal nature of these cognitive processes, which may help to identify the mechanisms to target during early interventions and treatments for adolescent pathological worry.

Executive functions are important cognitive abilities that involve goal-directed behaviours, which are important processes during adolescent development and are necessary to function in daily life. While previous studies have shown that impairments in attentional control and working memory are cognitive processes that are often associated with high worry, the present study did not support this. Future research in adolescents implementing experimental paradigms and reliable measures are needed to further examine the causal role of executive functions in adolescent worry. In particular, studies using a worry induction paradigm would enable researchers to assess directly the impact of worry on executive functions, rather than rely on retrospective questionnaires to measure worry. This is the aim of Chapter Six in the current thesis. A deeper understanding of how cognitive biases and executive functions operate during worry would provide valuable insight into the nature of worry in adolescents, which is a vulnerable age where habitual thought patterns may become stable well into adulthood.

Chapter 6

6

The Impact of Worry on Working Memory in Adolescents

Recent experimental studies in adults using worry induction paradigms have shown that high worry and anxiety predicts reduced working memory capacity. In contrast, the experimental literature on worry in youth has lagged behind, with most studies relying on retrospective self-report questionnaires to assess the cognitive correlates of worry. To address this gap in the literature, an experimental study was designed to investigate the direct effect of active worry on working memory capacity in adolescents, using a worry induction paradigm. Consistent with previous studies, the worry induction paradigm was effective in inducing greater levels of state worry and anxiety in a worry group compared to a control group. However, high worry did not impair performance on the verbal or visuospatial working memory tasks, as there were no differences on task performance between groups. Moreover, factors such as trait worry, trait anxiety, intolerance of uncertainty, attentional control, and emotional regulation did not influence adolescent's performance on the working memory tasks. The results indicate that executive functions may not play an important role in adolescent worry, however further research is warranted.

6.1. Introduction

In Chapter Five, we found that attentional control and working memory were not associated with worry in our sample of adolescents in the CogBias Longitudinal study. This was contrary to our expectations, given that previous studies in children and adolescents suggest that there is a relationship between high worry and poor attentional control and impaired working memory capacity (see Chapter Two for review). However, as discussed, one limitation in the youth literature is that studies are typically correlational in design and measure worry by means of a questionnaire to assess the content, frequency, and cognitive correlates of worry. In contrast, some adult studies examining the influence of worry on executive functions have implemented experimental paradigms that use worry inductions, which allow researchers to assess directly the impact of real-time worry on executive control processes, rather than rely on retrospective questionnaires. Only one study has examined the validity of a worry induction procedure in an adolescent sample (Frala et al., 2014), and thus the experimental literature on worry in youth has lagged behind. To address this gap in the literature and in line with adult research, the current study investigated the impact of worry on working memory in adolescents using a worry induction paradigm, in order to advance understanding of the cognitive pathways involved in adolescent worry.

Working memory involves the ability to store information in mind and mentally manipulate it to perform certain tasks such as reasoning, decision making, planning, incorporating new information and updating action plans, considering alternatives, and deriving relationships between new information and ideas (Diamond, 2013). Impairments in working memory capacity have been shown to relate to high worry and anxiety in adults (Moran, 2016). According to Baddeley and Hitch’s model (1994), working memory capacity is a limited cognitive resource comprised of a central executive system and two subsidiary systems for the processing of visuospatial and verbal information. The central executive acts as an attentional control system responsible for regulating thoughts and goals (Norman & Shallice, 1986) as well as the inhibition of automatic responses (Engle & Kane, 2004). The visuospatial system stores and processes visual or spatial based information, whilst the verbal system is a phonological loop in working memory that deals with the processing of speech and written information (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Together, these components of working memory have a limited capacity to store and manipulate information, with studies suggesting that most individuals can hold a maximum of seven items in working memory at any given time (Miller, 1956).

The attentional control theory (ACT; Eysenck et al., 2007) proposes that worry and anxiety consume the limited cognitive resources available in the central executive system, reducing working memory capacity to perform tasks. That is, individuals with high worry or anxiety find it difficult to ignore distracting thoughts and maintain attentional focus, thus taking up attentional resources and reducing task efficiency. A growing body of studies in adults provide evidence to support the notion that worry is associated with impaired working memory (Hayes et al., 2008; Leigh & Hirsch, 2011; Rapee, 1993; Sari et al., 2016; Stefanopoulou et al., 2014). In a study by Hayes and colleagues (2008), for instance, participants performed a random key-press task whilst engaging in worry or thinking about a positive topic. The results showed that high worriers, relative to low worriers, were less random in the key-press task during worry than when thinking about a positive topic. In contrast, low worriers were unaffected by topic content and performed better than high worriers in both conditions. These findings suggest that high worriers have a restricted working memory capacity when worrying and are less able to shift their attention away from worry to other tasks, compared to low worriers.

Similar results were replicated in a clinical sample (Stefanopoulou et al., 2014), where individuals diagnosed with GAD relative to healthy controls, were less random whilst performing a random key-press task during worry compared to thinking about a positive event. Furthermore, patients with GAD performed worse on a working memory task, the N-back task, during high load conditions, which required greater attentional control. These findings indicate that pathological worry consumes attentional control resources in working memory and decreases task efficiency (Berggren, Richards, Taylor, & Derakshan, 2013; Pacheco-Ungietti, Acosta, Callejas, & Lupianez, 2010).

Furthermore, Leigh and Hirsch (2011) found that high worriers, relative to low worriers, showed reduced working memory capacity when worrying in verbal form compared to imagery. Participants completed a random interval generation task, whilst engaging in worry in verbal or imagery form. The study demonstrated that verbal worry in high worriers depleted working memory resources more than worry in imagery form, whilst low worriers did not differ across mentation type. Similarly, Rapee (1993) examined the impact of performing tasks that assessed either the central executive, verbal, or visuospatial processing systems of working memory, whilst simultaneously engaging in worry. The study found that only one of the tasks that involved verbal processing, interfered with worry, which suggests that worry is a verbal process that impairs executive functions. Broadly, these findings in adults indicate that worry is a verbal process that serves as a cognitive avoidance function in response to more potent and distressing visual imagery (Bergman & Craske, 2000; Borkovec, Alcaine, & Behar, 2004; Freeston, Dugas, & Ladoucer, 1996). This is supported by studies that have shown verbal thoughts are more prevalent in adult pathological worriers compared to non-clinical populations (Borkovec & Inz, 1990; Sibrava & Borkovec, 2006) and this verbal form of worry appears to maintain negative intrusions compared to imagery-based worry (Stokes & Hirsch, 2010). Therefore, evidence suggests that the verbal nature of worry in adults is debilitating and depletes working memory resources.

Consistent with the adult literature, research indicates that worry is associated with impaired working memory in adolescents. As reviewed in Chapter Two, evidence shows that reduced working memory capacity is associated with high worry and GAD in adolescents, and is an important cognitive process involved in adolescent worry (Owens et al., 2012; Trezise & Reeve, 2014, 2016). Trezise and Reeve (2014, 2016), for instance, used a novel Algebraic Working Memory task to investigate the effect of worry on working memory in relation to academic performance in adolescent girls. The study found that high worry and low working memory were associated with poor problem solving performance, whilst low worry and high working memory were related to high problem solving performance (Trezise & Reeve, 2014). Moreover, this relationship was stable over time as worry and working memory were assessed several times over the course of a day as adolescents prepared for a maths test (Trezise & Reeve, 2016). The results showed that high worry predicted decreases in working memory, whilst low working memory caused increases in worry.

Similarly, another study investigated the association between negative affect, worry, academic performance, and working memory using the digit span and spatial span tasks in adolescents (Owen et al., 2012). Complex span tasks with neutral stimuli (Conway et al., 2005; Kane et al., 2004) and affective stimuli (Schweizer & Dalgleish, 2011, 2016) have traditionally been used as reliable predictors of working memory capacity and higher order executive functions. The study found that high worry and working memory mediated the relationship between anxiety, depression, and academic performance, which suggests that worry and working memory processes are cognitive mechanisms underlying the relationship between negative affect and lowered academic performance. Together, these findings in adolescence indicate that worry interferes with working memory capacity and provides support for the ACT (Eysenck et al., 2007) and the cognitive model of pathological worry (Hirsch & Matthews, 2012), which proposes that worry consumes the limited cognitive resources in working memory and diminishes task efficiency and performance.

Whilst research in adolescents provide support for the association between worry and deficits in working memory, one limitation to the studies is that they are correlational in design and do not assess the direct effect of active worry on working memory. Therefore, the present study investigated the impact of active worry on working memory capacity in adolescents using a worry induction paradigm that has been validated in adolescent (Frala et al., 2014) and adult studies (McLaughlin, Borkovec, & Sibrava, 2007; McLaughlin, Mennin, & Farach, 2007). Specifically, in line with the adult literature, the present study examined the direct influence of active worry on the visuospatial and verbal processes of working memory to provide further insight into the nature of worry in adolescents and identify the components of working memory that are impaired during worry.

Firstly, we hypothesised that adolescents in the active worry condition would report higher levels of worry and state anxiety from pre-induction to post-induction compared to the control condition. Secondly, we predicted that adolescents in the worry condition would perform worse on the visuospatial and verbal working memory tasks, compared to the control condition. Thirdly, we hypothesised that differences in the worry and control group's performance on the working memory tasks, would depend on levels of trait worry, trait anxiety, intolerance of uncertainty, attentional control, and emotion regulation.

To the best of our knowledge, this is the first study to assess the impact of active worry on working memory in adolescents and the influence on visuospatial and verbal processing in the central executive system of working memory. In line with the adult literature, experimental studies that involve actively engaging in the worry process during task performance will advance our current knowledge of the causal pathways and direct effect of worry on working memory capacity in adolescents. Importantly, a deeper understanding of how worry influences working memory processes in adolescents, would provide greater insight into the cognitive mechanisms underlying pathological worry and help to identify the potential targets to improve current interventions for worry in youth.

6.2. Method

Participants

Participants were 63 adolescents (31 males, 32 females) aged 14 to 16 years old (M = 14.33, SD = .82), who were recruited through secondary schools in Oxfordshire, England. The participating schools were co-educational and consisted of private and comprehensive schools, which were independent from the schools recruited for the CogBias Longitudinal study. The target age group was selected because worry becomes more abstract during mid-adolescence and is an important stage for cognitive development. In addition, the narrow age range was selected in order to reduce the influence of confounding developmental factors in participant’s ability to worry. Participants were recruited by writing emails to head teachers describing the aims of the study and three schools responded with interest to take part in the research. In addition, flyers and posters were placed around the community to recruit participants. Parental consent was obtained by sending an information pack to parents via email or in paper form, which contained a parent information sheet, an adolescent information sheet, a parent consent form, and demographic questionnaire. Participants were recruited using an opt-in method and participation in the study was voluntary. Adolescents did not receive monetary compensation, instead participating schools and participants were offered enrichment activities such as talks about psychology and work experience opportunities in our lab at the University of Oxford.

Participants eligible to take part in the study were adolescents in secondary school aged between 14 to 16, being fluent in English, and having a parent and adolescent able to give written informed consent or assent. Participants were excluded from the study if they were currently suffering from a psychological disorder and any neurological impairment or learning disability that would make them unable to take part. The inclusion and exclusion criteria was determined by parental self-report on the demographics questionnaire. Demographic information was collected from parents, and of the participants, 84% were White or European, 10% were from mixed background, 3% were South Asian, and 3% were of African or Caribbean decent. Parents who responded to questions about education indicated that the highest level of education attained was a Bachelor’s degree (37%) followed by a Master’s degree (31%), vocational training (12%), some college (10%), Doctoral degree (6%), and secondary school (4%). No participants withdrew from the study.

Measures

Self-report measures

Worry. The Penn State Worry Questionnaire for Children (PSWQ-C; Chorpita et al., 1997) is a 14 item self-report measure used to assess the tendency to worry in children aged 6 to 18 years old (see Appendix B). Examples of items include; “My worries really bother me” and “I know I shouldn’t worry, but I just can’t help it.” Each item was rated on a 4-point Likert scale (0 = Never true to 3 = Always true) and a total was calculated by summing the items. Higher scores on the PSWQ-C indicate more frequent and uncontrollable worries. The PSWQ-C has excellent internal consistency, good convergent and discriminant validity, and test-retest reliability in clinical and non-clinical adolescent samples (Chorpita et al., 1997;

Pestle et al., 2008). The internal consistency of the PSWQ-C in the current study was high (α = .92).

Anxiety. The Revised Children's Anxiety and Depression Scale - Short Form (RCADS-SF; Ebesutani et al., 2012) is a 25-item self-report questionnaire used to assess anxiety and depression symptoms (see Appendix I). The RCADS-SF comprises six subscales corresponding to separation anxiety, generalized anxiety, panic disorder, social anxiety, obsessive compulsive disorder, and depression. Items are scored on a 4-point Likert scale ranging from 0 ("Never") to 3 ("Always"). The items corresponding to anxiety are summed to yield an Anxiety total score, with higher scores indicating higher symptoms of anxiety in adolescents. The RCADS-SF is derived from the original 47-item questionnaire (Chorpita et al., 2000) and has shown to have good reliability and validity in children and adolescents (Chorpita, Moffitt, & Gray, 2005). The internal consistency for the current study was high (α = .93)

Emotion regulation. The Emotion Regulation Questionnaire for Children and Adolescents (ERQ-CA; Gullone & Taffe, 2012) is designed to assess individual differences in the use of emotion regulation strategies. The ten items (see Appendix J) measure cognitive reappraisal (six items) and expressive suppression (four items). Items are rated on a 5-point Likert- scale, with higher scores indicating greater use of the emotion regulation strategy. The ERQ-CA has demonstrated good internal consistency and adequate 4-week test–retest reliability (Gullone & Taffe, 2012; MacDermott, Gullone, Allen, King, & Tonge, 2010). Good convergent and construct validity has also been reported with other emotion regulation scales and a variety of measures such as temperament (Betts, Gullone, & Allen, 2009). The internal consistency for the reappraisal subscale was good (α = .85) and the expressive subscale was adequate (α = .70).

Attentional control. The Attentional Control Scale – Child version (ACS-C; Derryberry & Reed, 2002) measures self-reported attentional control abilities. The 20 items relate to respondents perceived ability to concentrate on a task at hand, switch attention between tasks, and to flexibly control thought (see Appendix K). Items are scored on a 4-point Likert scale ranging from 1 (Almost never) to 4 (Always), with higher total scores reflecting higher levels of attention control. The ACS-C total score has shown to have good internal consistency and psychometric properties (Derryberry & Reed, 2002). The internal consistency for the current study was high (α = .81).

Intolerance of Uncertainty. The Intolerance of Uncertainty Scale for Children (IUS-C; Comer et al., 2009) is a 27-item questionnaire that measures children's intolerance of uncertainty (see Appendix L). Items on the IUS-C require children to rate the degree to which they agree with statements on a 5-point Likert-scale ranging from 1 (Not at all) to 5 (Very much). Higher scores indicate greater intolerance of uncertainty. The IUS-C has shown excellent internal consistency for both community samples and anxiety-disordered samples of youth aged 7 to 17 (Comer et al., 2009). The internal consistency for the current study was high (α = .95).

Visual analogue scale. Visual Analogue Scales (VAS) were used to assess current mood states and the extent to which participants felt worried, anxious, relaxed, and happy (see Appendix M). In the current study the inclusion of relaxed and happy mood states on the VAS were obtained to reduce the sole focus on worry or anxiety, which may enhance anxious mood and lead to demand effects. Participants rated the extent to which they felt worried, anxious, relaxed or happy on 0-100 mm visual analogue scales (VAS) ranging from 0 (Not at all) to 100 (Extremely).

State anxiety. The State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a commonly used measure comprised of two separate 20-item scales. The State scale (STAI-S) assesses situational anxiety (e.g. asking people to report on how they feel right now), whereas the Trait scale (STAI-T) measures dispositional anxiety (e.g. asking people to report on how they generally feel). Items are rated on a 4-point Likert scale resulting in scores ranging from 20 to 80, with higher scores indicating higher levels of anxiety. Both scales have good internal consistency and have demonstrated excellent test-retest reliability (Elliott, Shewchuk, & Richards, 2001; Shewchuk, Richards, & Elliott, 1998; Spielberger et al., 1983; Spielberger, 1989). The STAI-S was used for the current study (see Appendix N) and the internal consistency was high ($\alpha = .92$).

Cognitive tasks

Verbal working memory. The Forwards and Backwards Digit Span task (Woods et al., 2011) was used to measure verbal working memory (see Appendix O). Participants were required to wear headphones to listen to a sequence of auditory digits. A red circle appeared in the middle of the computer screen for 1000ms, as a visual signal to indicate that the audio for the sequence of digits would begin. When the red circle disappeared, participants heard a sequence of digits from one to nine. At the end of the sequence another red circle appeared for 1000ms, after which the participants were instructed to recall the digit sequence and type their response into a textbox presented in the middle of the computer screen using the numbers on the keyboard. In the Digit Span Forward task, participants were required to recall numbers in the same order as they were presented in the audio. Whilst in the Digit Span Backwards task, participants recalled the numbers in the reverse order of that presented in the audio.

There were 14 trials for the Digit Span Forward task, which was presented first. This was followed by 14 trials of the Digit Span Backwards task. Participants were presented with two practice trials at the beginning of each block to familiarise themselves with the task and no data was recorded during this period. For the forwards assessment, all participants started on a level three trial sequence (i.e. three auditory digits) and for the backwards assessment, all participants started on a level two trial sequence (i.e. two auditory digits). In line with previous studies, the 1:2 staircase method of increasing or reducing the digit sequence for each trial was used. Based on the performance of each trial, participants moved up a level or down a level. If the response was correct (in digits and presentation order), the participant moved up to the next level. However, if the response was incorrect, the same level was presented a second time. If a consecutive error occurred, the participant moved back down to a lower level, starting over. Forward and Backwards Digit Span was calculated, using the traditional measure, of the last digit span a participant gets correct, before making two consecutive errors. The list of digit sequences were randomised and selected from a pool of semi-randomly constructed digit sequences that met the following constraints; digits from one to nine only, no repeated digits, no equal distances between 3 consecutive digits, and no repeated sequences. Participants were not given feedback after each trial on their correct or incorrect response, however a summary of results were presented at the end of the task.

Visuospatial working memory. The Symmetry Span task (Kane et al., 2004) was used to measure visuospatial working memory (see Appendix P). Participants were required to memorise and recall a sequence of red square locations, whilst simultaneously performing a symmetry-judgement task. In the symmetry-judgement task, an 8 x 8 square matrix was presented on the computer screen with a pattern of black and white square designs. When the square matrix disappeared, participants had to decide whether the design was symmetrical along the vertical axis by using the mouse to select a 'yes' or 'no' button presented on the screen. Immediately following the participants response to the symmetry-judgement task, a 4 x 4 square matrix was presented on the screen with one of the squares filled in red for 650ms. Participants were required to remember the location of the red square and hold that piece of information in their memory, before the next symmetry-judgement display was presented on the screen. At the recall phase, participants recalled the sequence of red square locations, in the order they appeared, by clicking on the cells of a blank 4 x 4 matrix.

The Symmetry Span task comprised of four blocks. The first three blocks consisted of practice trials and no data was recorded during this period. This was conducted to ensure participants understood the processing components of the task. In Block one, participants practiced the symmetry-judgement component of the task and were shown 15 patterns of displays to judge whether they were symmetrical. Participants then practiced the recall part of the task in Block two, where participants had to remember the location of the red squares presented in the matrix. In Block three, participants were given three practice trials which included both the symmetry-judgement and recall components of the task. For the actual assessment (Block four), there were 12 trials in total and each trial sequence comprised of a symmetry-judgement display followed by a matrix showing the location of a red square. The set sizes ranged from two to five symmetry-judgement displays per trial and there were three trials for each set size (i.e. 12 in total). The order of the set sizes were randomised for each trial and participants were given feedback after each trial on their correct or incorrect response. In addition, the presentation of the symmetry-judgements displays were randomised and symmetrical 50% of the time. In line with previous studies, Symmetry Span was calculated using the partial span scoring method, which is the sum of items recalled in the correct serial position, regardless of whether the entire trial was recalled correctly (Foster et al., 2015; Oswald, McAbee, Redick, & Hambrick, 2015; Redick et al., 2012).

Procedure

The testing sessions were arranged at participating schools during normal lessons (*N* = 60) or at the Department of Experimental Psychology, University of Oxford (*N* = 3). Each testing session lasted approximately one hour and was conducted in a quiet room individually with a researcher present. Upon arrival, participants were informed about the study procedures, confidentiality, and that they could withdraw at any time. Participants were told that the study was investigating adolescent worry and *"how worrying in young people is related to different thinking styles such as the way we process and interpret information around us."* Adolescents were required to provide written and informed assent before beginning the experiment and were given the opportunity to ask any questions throughout. Ethical approval for the study was obtained from CUREC (reference: R46605/RE001).

Participants were randomly assigned to either a Worry (*N* = 32) or a Control group (*N* = 31) using the website www.random.org. The testing session comprised of a Baseline period, Induction period, and Post-induction period (see Figure 6.1.). This experimental procedure was based on previous studies, which have been validated in adult and adolescent populations (McLaughlin et al., 2007; Frala et al., 2014). In the Baseline period, participants in both groups were instructed to sit quietly in the room with their eyes closed and think about anything they wish for five minutes. Following this Baseline period, participants provided mood ratings using the STAI-S and VAS measures on the extent to which they felt worried, anxious, relaxed, or happy. This was assessed to obtain baseline measures of current mood states (i.e. pre-induction).

For the Induction period, the researcher guided the participants through one of two instructional sets, worry or neutral, depending on the group to which the participant had randomly been assigned. In the Worry condition, participants were given a standard definition of worry drawn from the Anxiety Disorders Interview Schedule for Children (ADIS-C) - *"Worry is when you keep thinking about things over and over and it's hard to stop thinking about it. The things you are thinking about are usually things that might happen in the future that you feel nervous or afraid about"* (Silverman & Albano, 1996, p. 41). The researcher read the definition of worry aloud to participants and also provided the definition on paper for participants to refer to throughout the study. Following this, participants were instructed to write down three topics of future events that they frequently worry about the most to be used for the worry induction. Participants were then read a standard script with instructions adapted from McLaughlin et al. (2007) and Frala et al. (2014).

"During this period, we would like you to create a worried state of emotion. Please refer to your list of worry topics you wrote down. When I ask you to begin, please close your eyes and worry about your most worrisome topic, in the way you usually worry about it but as intensely as you can, until I ask you to stop and to open your eyes. If you normally worry about only one topic at a time, please try to do the same during this period. However, if your thoughts change to another worry topic that you usually worry about during this period feel free to allow these thoughts to continue. It is alright to change topics during this period if the changes usually happen when you worry."

In the Control condition, participants were instructed to write down three neutral topics of future events such as ordinary everyday things that do not result in strong feelings (e.g. watching television or reading). Participants were then read a standardised script, designed to match the Worry condition.

"During this period, we would like you to create a neutral state of emotion, not good or bad, just in the middle. Please refer to your list of neutral topics you wrote down. When I ask you to begin, please close your eyes and think about the neutral topics on your list in the way you usually think about it, until I ask you to stop and to open your eyes. If you normally think about only one neutral topic at a time, please try to do the same during this period. However, if your thoughts change to another neutral topic that you usually think about during this period feel free to allow these thoughts to continue. It is alright to change topics during this period if the changes usually happen when you think about neutral things."

At the end of the five-minute Induction period, participants provided mood ratings using the STAI-S and VAS to check that the worry manipulation was successful (i.e. post-induction). Directly following the Induction period, participants were instructed to complete the cognitive tasks and questionnaires as quickly and accurately as possible. During this time, the worry (or neutral) topics that participants had written down were placed next to them, in order to increase the proximity of worrisome thoughts and further assess the effect of worry on working memory task performance. Participants were also instructed to keep thinking about their worrisome (or neutral) topics while they completed the task. The order of presentation of the Digit Span and Symmetry Span tasks were counterbalanced and after completion of the task, participants provided mood ratings using the STAI-S and VAS (i.e. post-completion of the tasks).

In the Post-induction period, after completion of the cognitive tasks and questionnaires, a positive mood induction was administered to all participants to ensure that they did not leave in a worried state and mood ratings were obtained. Therefore, mood ratings were assessed at four time points, at pre-induction, post-induction, post-completion of the cognitive tasks, and post-experiment. In line with a previous study, adolescents watched a short segment from a Mr. Bean slapstick comedy episode (Frala et al., 2014). At the conclusion of the experimental procedure, participants were debriefed regarding the objectives of the study and any questions or concerns were addressed.

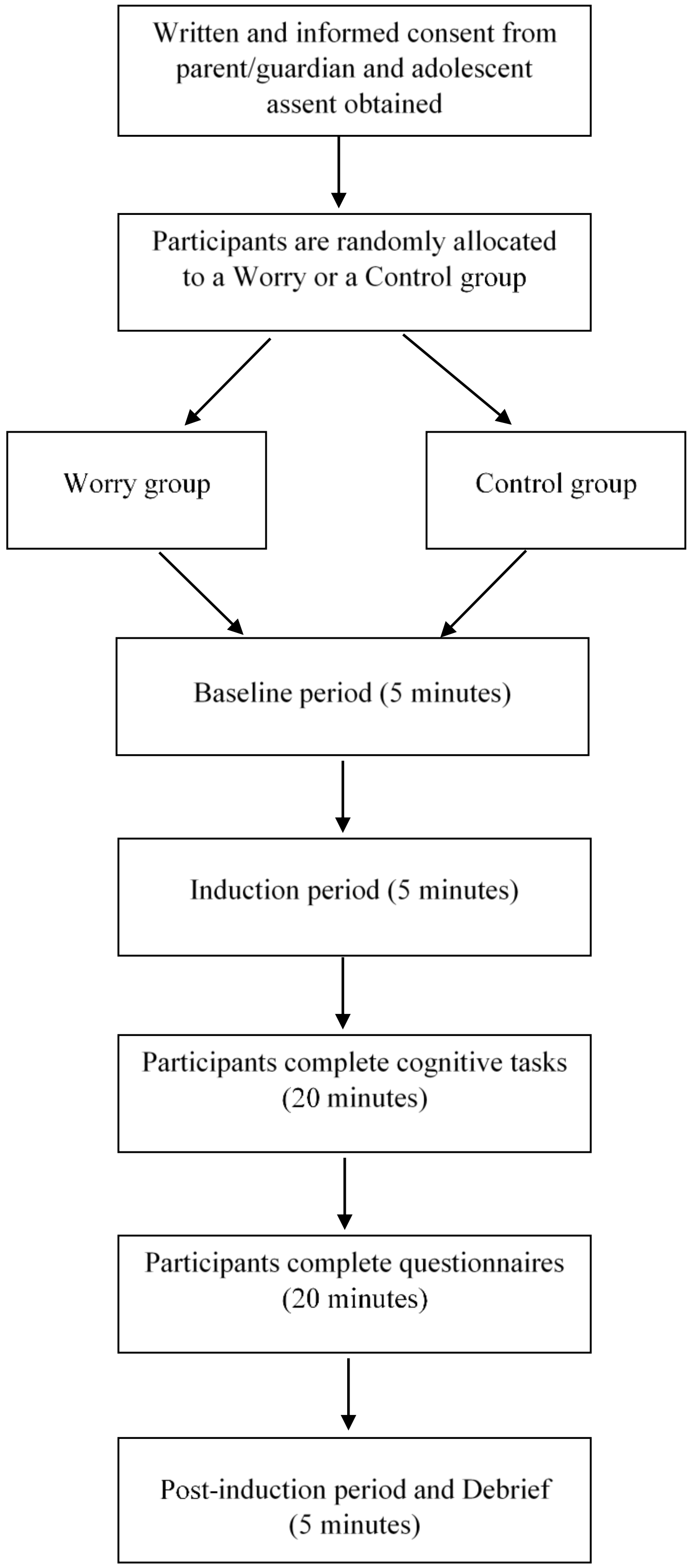

Figure 6.1. Flow chart for experimental procedure

Data Analysis Plan

Preliminary analysis

Independent sample t-tests (for continuous variables) and chi-sqaure analysis (for categorical variables) were conducted to examine demographic characteristics of the sample and baseline differences between the worry and control groups. In addition, bivariate correlations between the variables were examined to identify the level of associations between the variables.

Worry induction manipulation check

To assess whether the worry induction was effective, a mixed ANOVA involving time as a within-subjects factor (pre-induction, post-induction, post-completion of the cognitive tasks) and group (worry, control) as the between subjects factor was conducted separately on the worry VAS and STAI-S scores. Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(2) = 7.83$, $p = .020$, therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .89$) and are reported in the analyses.

Performance on working memory tasks

To assess the main hypothesis of whether there were any differences in adolescent's performance on the verbal and visuospatial working memory tasks based on their allocation to an active worry or control group, a one-way MANOVA was performed. The dependent variables were scores on the working memory tasks (forwards digit span, backwards digit span, symmetry span) with a between-subjects factor of group (worry, control). Multivariate analysis using a MANOVA was performed as there was more than one dependent variable and this analysis has greater statistical power in detecting an effect when the dependent variables are correlated, assesses the pattern of relationships between the correlated dependent variables, and controls for type 1 error. Preliminary analyses were conducted to ensure that there were no violations of the assumptions to perform the MANOVA.

To address the third hypothesis, separate one-way MANCOVA’s were performed to investigate whether there were any differences between the groups in terms of performance on the working memory tasks, after controlling for levels of trait worry, trait anxiety, intolerance of uncertainty, attentional control, and emotion regulation. Covariates were entered in the analysis to examine whether the effect of group (worry, control) on overall performance on the working memory tasks (digit span forwards, digit span backwards, symmetry span), depended on the degree of trait measures. Tests of normality for the analysis were conducted using Box's test of equality of covariance matrices and Levene's test of equality of error variances, with non-significant effects indicating normality.

The number of participants for this study (N = 63) were selected due to time and resource limitations, as well sample size estimations based on previous studies using this worry induction paradigm in adolescents (Frala et al., 2014) and adults (McLaughlin, 2007). However, a post-hoc power analysis was performed using the software package G*Power (Faul et al., 2007) to determine the estimated power and sample size needed for statistical power of .08. The power of this study was considered to be medium (0.33) using Cohen’s criteria (1988). Furthermore, with an alpha set at .05 and power of 0.80, the projected sample size needed was approximately N = 20 for this between group comparison. Therefore, our sample size of N = 63 was adequate for the main objective of this study, to compare the worry and control group’s performance on the working memory task.

Missing data

There was no missing data for participants on the Worry VAS and STAI-S measures across the four time points of the worry induction procedure ($N = 63$). In addition, there was no missing data on the Digit Span and Symmetry Span working memory tasks ($N = 63$). However, due to a technical fault, there was missing data for one participant on the PSWQ-C, RCADS-SF, IUS-C, ERQ-CA, and ACS-C questionnaire measures ($N = 62$). The subsequent analyses were performed excluding the participant with missing data.

6.3. Results

Descriptive Statistics

Groups (worry, control) did not differ significantly with regard to age ($t(61) = 1.66$, $p = .100$; $d = 0.40$) and chi-square tests identified no between-group differences on demographic characteristics such as gender, school, SES, and ethnicity (all *ps* >.05). Furthermore, groups did not differ on baseline measures on the VAS or STAI-S and no between group difference emerged on the PSWQ-C, RCADS, IUS-C, ERQ-CA, and ACS-C (all *ps* >.05), indicating that groups were comparable and no differences existed prior to the worry induction. See Table 6.1. for demographic characteristics.

The mean level of trait worry (PSWQ-C) for the sample was $M = 23.71$ ($SD = 9.36$), with females ($M = 27.50$, $SD = 7.78$) showing significantly higher levels of worry compared to males ($M = 19.67$, $SD = 9.23$); ($t(60) = -3.60$, $p = .001$; $d = 0.90$). No significant correlations were observed between worry and age, or worry and SES (*ps* >.05), as well as no differences in SES amongst the school cohorts ($F(3, 51) = 2.58$, $p = .070$, partial $\eta^2 = .14$). However, a one-way ANOVA revealed a statistically significant difference in mean levels of worry among the school cohorts ($F(3, 61) = 4.95$, $p = .004$, partial $\eta^2 = .20$). The sample demographics and mean levels of worry in adolescents in the current study are consistent with the results presented in the previous chapters of the CogBias Longitudinal study sample. All bivariate relationships between the variables were examined and were in the expected directions (see Table 6.2). The dependent variables of the forwards digit span, backwards digit span, and symmetry span scores were low to moderately correlated.

Table 6.1

Sample Characteristics of Participants

	Worry group (n = 32)		Control group (n = 31)		Total (n = 63)		Statistic
Variable	n	%	n	%	n	%	
Gender							
Male	16	52	15	48	31	49	$\chi^2 = .02$, $p = .90$
Female	16	50	16	50	32	51	
Age							
Mean (SD)	14.5 (.76)		14.16 (.86)		14.33 (.82)		$t = .17$, $p = .10$
Range	13-16		13-16		13-16		
Parent's Education							
Doctoral	2	67	1	33	3	6	$\chi^2 = 8.58$, $p = .57$
Masters	6	38	10	62	16	31	
Bachelor	8	42	11	58	19	37	
Vocational Training	5	83	1	17	6	12	
Some College	2	40	3	60	5	10	
Secondary School	2	67	1	33	3	4	
Ethnicity							
White or European	25	47	28	53	53	84	$\chi^2 = 8.16$, $p = .06$
Mixed Background	5	83	1	17	6	10	
South Asian	0	0	2	100	2	3	
African or Carribean	1	50	1	50	2	3	

Table 6.2

Correlations of Variables

Variable	1	2	3	4	5	6	7	8
1. Forwards Digit Span								
2. Backwards Digit Span	.63**							
3. Symmetry Span	.25*	.32*						
4. Worry	.27*	.23	-.01					
5. Anxiety	.07	.05	-.07	.70**				
6. Intolerance of Uncertainty	.09	.02	-.18	.78**	.79**			
7. Attentional Control	-.04	.07	.11	-.47**	-.46**	-.48**		
8. Reappraisal	-.22	-.09	-.14	-.15	-.15	-.18	.26*	
9. Suppression	.09	.23	.12	.23	.31*	.29*	-.02	-.16

Note. * p < .05 ** p <.01

Worry Induction Manipulation Check

Participants reported their current levels of worry (Worry VAS) and state anxiety (STAI-S) at four time points throughout the experiment; pre-induction, post-induction, post-completion of the cognitive tasks, and post-experiment after the positive mood induction. To ensure that the worry induction was effective and participants in the worry group experienced an increase in worry or state anxiety during the induction period, and participants in the control group did not experience an increase in worry or state anxiety, changes in VAS and STAI-S scores across pre-induction, post-induction, and post-completion of the tasks were examined. A mixed ANOVA with time (pre-induction, post-induction, post-completion of the cognitive tasks) as a within-subjects factor and group (worry, control) as a between subjects factor was conducted on the worry VAS and STAI-S scores. The analysis for the worry VAS scores revealed a significant main effect of time ($F(1.86, 113.58) = 5.41$, p =.007, partial η^2 =.08), indicating that the worry VAS scores differed across the time points in the induction period. In addition, a significant main effect of group ($F(1, 61) = 5.10$, p = .027, partial η^2 =.08) emerged, indicating that the worry and control groups differed in their levels of worry on the VAS. Furthermore, the results showed a significant time by group interaction ($F(1.86, 113.58) = 6.65$, p =.002, partial η^2 =.10), demonstrating that the mean worry VAS scores in the worry and control groups were significantly different across the time points in the worry and control groups.

Pairwise comparisons, adjusting for Bonferroni corrections, indicated that participants in the worry group reported an increase in worry VAS scores from pre-induction (M = 26.42) to post-induction (M = 47.81). Furthermore, participants in the worry group reported significantly higher levels of worry compared to the control group at post-induction, indicating that the worry induction was effective. However, in the worry group, there was a decrease in worry scores from post-induction to post-completion of the cognitive tasks (M =

34.65), suggesting that worry was not maintained throughout completion of the cognitive tasks. In the control group, there were no significant changes in worry scores across time points (see Figure 6.2).

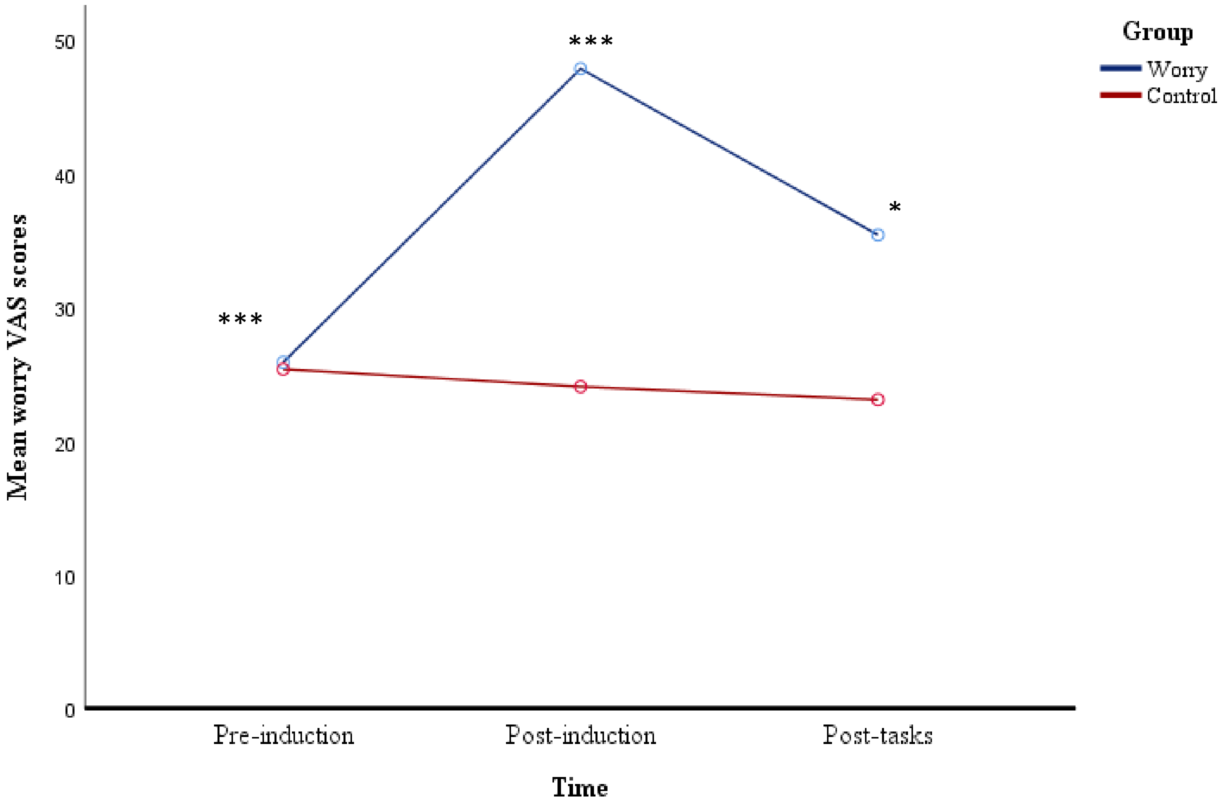

Figure 6.2. Worry (VAS) ratings across induction period by group

Note. ***p <.001, *p <.01

Similarly, the analysis for state levels of anxiety (STAI-S) revealed a significant main effect of time ($F(1.85, 112.57) = 3.95$, p =.025, partial η^2 =.06), a significant main effect of group ($F(1, 61) = 4.49$, p =.038, partial η^2 =.07), which was qualified by a time by group interaction ($F(1.85, 112.57) = 16.29$, p <.001, partial η^2 =.21). This indicates that the mean scores on the STAI-S were significantly different across the time points in the worry and control groups. Pairwise comparisons, adjusting for Bonferroni corrections, indicated that participants in the worry group reported an increase in state anxiety scores from pre-induction (*M* = 39.55) to post-induction period (*M* = 48.94). In contrast, participants in the control group, reported a decrease in STAI-S scores from pre-induction (*M* = 40.70) to post-induction (*M* = 36.70). Participants in the worry group reported significantly higher state anxiety compared to the control group at post-induction, suggesting that the induction was effective in eliciting anxious mood states. However, levels of state anxiety in the worry group significantly decreased from post-induction to post-completion of the cognitive tasks (*M* = 42.42), suggesting that worry levels may not have been maintained whilst completing the task (see Figure 6.3.).

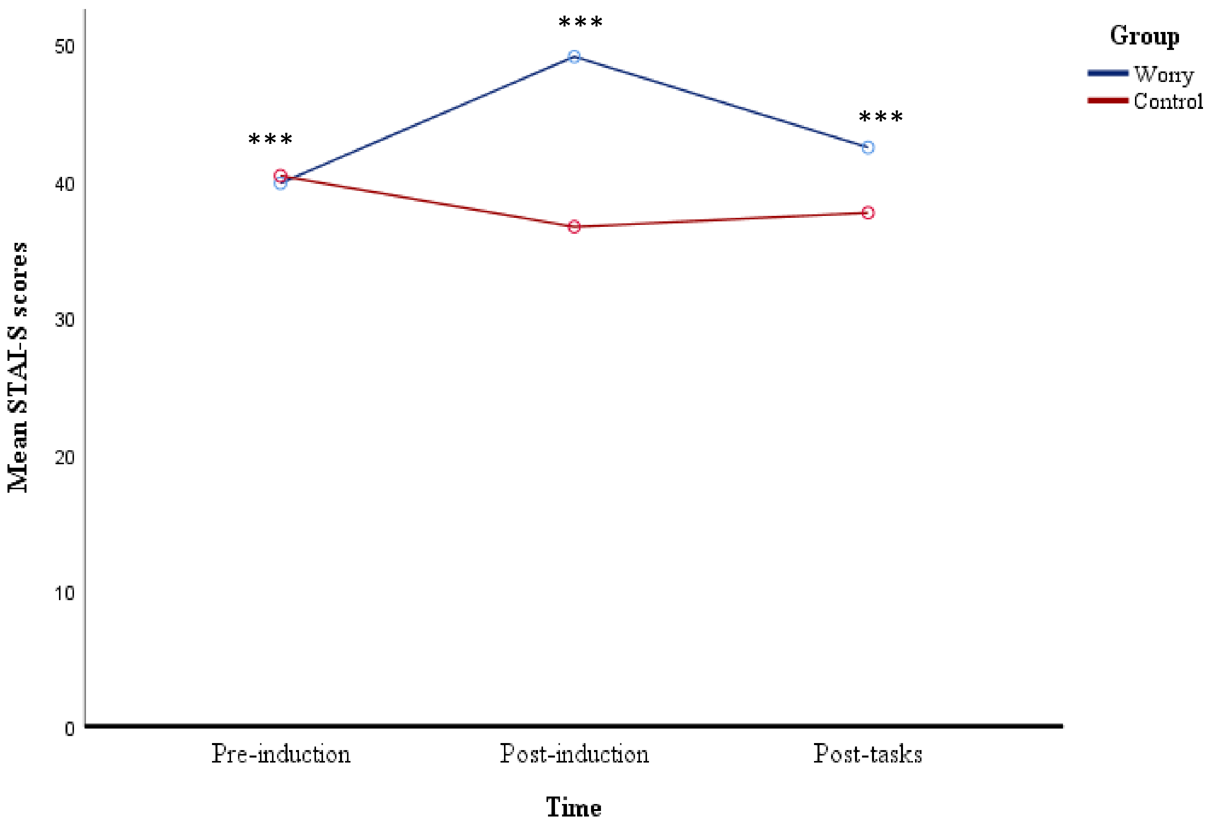

Figure 6.3. Anxiety (STAI-S) ratings across induction period by group.

Note. ****p* <.001, **p* <.01

In addition, levels of state worry and state anxiety reported after the positive mood induction indicated that all participants left the study in a significantly less worried (worry group M = 22.32, control group M = 18.83) or anxious state (worry group M = 34.19, control group M = 33.57) from post-induction to post-experiment. Furthermore, there was no significant difference in levels of worry or anxious state between participants in the worry and control groups at post-experiment. Analysis of the positive mood VAS scores at post-experiment also revealed no significant differences in happy or relaxed mood states in participants in the worry and control condition at post-experiment, indicating that the positive mood induction was effective. Mean and standard deviations across the different time points are presented in Table 6.3.

Table 6.3

Mean Mood Ratings for the Worry and Control Groups Across the Induction Period (standard deviation in parenthesis)

Time	Worry (VAS)		Anxiety (STAI-S)	
	Worry	Control	Worry	Control
Pre-induction	26.42 (4.62)	25.40 (4.70)	39.55 (2.02)	40.70 (2.05)
Post-induction	47.81 (4.97)	24.07 (5.05)	48.94 (2.21)	36.70 (2.25)
Post-tasks	34.65 (4.53)	23.90 (4.61)	42.42 (2.14)	37.93 (2.18)
Post-experiment	22.32 (3.77)	18.83 (3.83)	34.19 (1.79)	33.57 (1.18)

Performance on Working Memory Tasks

A one-way MANOVA was conducted with the forwards digit span, backwards digit span, and symmetry span scores as the dependent variables, comparing the between-subjects factors of group (worry, control). There was no significant main effect of group (F(3, 59) =

1.29, p =.308, partial η^2 =.06), indicating no differences between the worry and control group in terms of their performance on the working memory tasks. Mean scores on the working memory tasks are presented in Table 6.4.

Table 6.4

Mean Scores on the Working Memory Tasks for the Worry and Control Group

Group	Worry	Control
Forwards Digit Span	6.53 (1.27)	6.19 (1.22)
Backwards Digit Span	5.28 (1.57)	5.19 (1.33)
Symmetry Span	27.94 (6.45)	29.74 (4.91)

Separate MANCOVA's with trait worry (PSWQ-C), trait anxiety (RCADS-SF), intolerance of uncertainty (IUS-C), attentional control (ACS-C), and emotion regulation (ERQ-CA) as covariates were conducted to examine whether there were any differences between the groups in terms of performance on the working memory tasks, after controlling for trait measures. There was no statistically significant difference between the groups on the combined dependent variables, after controlling for trait worry (F(3, 57) = 1.18, p =.324, partial η^2 =.06), trait anxiety (F(3, 57) = 1.04, p =.380, partial η^2 =.05), intolerance of uncertainty (F(3, 57) = 1.08, p =.367, partial η^2 =.06), attentional control (F(3, 57) = 1.10, p = .355, partial η^2 =.06), and the emotion regulation strategies of reappraisal (F(3, 57) = 1.30, p = .284, partial η^2 =.06) or suppression (F(3, 57) = 1.03, p =.387, partial η^2 =.05).

6.4. Discussion

The present study investigated the impact of worry on working memory in adolescents using a worry induction paradigm to assess the causal effect of active worry on visuospatial and verbal processing in working memory. The results provided support for the first hypothesis that adolescent's in the worry group compared to the control group, showed higher levels of state worry and state anxiety following the worry induction paradigm, indicating that the worry induction was effective. However, contrary to the second hypothesis, state worry and state anxiety did not impair adolescent's performance on the working memory tasks. The results showed that there were no significant differences between the worry and control group's performance on the visuospatial or verbal working memory tasks. Furthermore, the third hypothesis was not supported as there were no group differences on working memory capacity based on adolescent's levels of trait worry, trait anxiety, intolerance of uncertainty, attentional control, or emotion regulation. Therefore, in the present study, the worry induction procedure was effective in inducing greater levels of state worry and state anxiety in the worry group compared to the control group, although contrary to our predictions, this did not have an impact on adolescent's working memory capacity.

A wealth of empirical research in adults have utilised the experimental approach of worry induction paradigms and catastrophizing interviews to investigate the consequences of worry, which have contributed to a greater understanding of worry in adults (Behar, Zuellig, & Borkovec, 2005; Borkovec, Ray, & Stöber, 1998; McLaughlin et al., 2007; Meeten & Davey, 2011). In contrast, the experimental literature on worry in youth has lagged behind and predominantly focused on correlational designs with retrospective self-reports on questionnaires, vignette presentations, and interviews to assess the content, frequency, and cognitive correlates of worry (see Chapter Two). The present study extends the current literature by experimentally testing the validity of a worry induction paradigm in a healthy sample of adolescents, with only one study to date that has used a worry induction in adolescents (Frala et al., 2014). Consistent with previous studies, the worry induction paradigm was effective in inducing greater levels of state worry and state anxiety from pre-induction to post-induction in a worry group compared to a control group. As predicted, the worry group reported increased worry and anxiety from pre to post induction, whilst the control group showed a decrease in state worry and anxiety during the induction period. Furthermore, levels of worry and anxiety were higher in the worry group compared to the control group at post-induction. These findings support the use of a worry induction procedure in eliciting increased negative affectivity and a worry-relevant affective state in adolescents (Newman & Llera, 2011), which is a useful approach for future studies to better understand the causal nature and consequences of worry in youth.

In the present study, we adapted a previous worry induction in adolescents (Frala et al., 2014) to include simple VAS scales to measure worry, anxious, happy, and relaxed mood states as well as the STAI-S to assess state anxiety at four time points throughout the experiment. Previous studies included multiple measures to assess negative affect during the induction period (Frala et al., 2014; McLaughlin et al., 2007), which participants completed every sixty seconds during the five-minute worry induction procedure (i.e. five times). Due to time constraints and to minimise interruptions during the induction period, we measured mood states only at pre and post induction and found similar results, which suggests that a shorter adapted version of the worry procedure without multiple interruptions and frequent mood ratings is also effective in adolescents. Furthermore, in the current study we instructed participants in the worry condition to write down three worrisome thoughts on a piece of paper, in addition to thinking about the worrisome topics, which participants kept next to them throughout the experiment. This was included in order to make the active worry state more salient during the experiment and to address the limitation that worry is often measured with questionnaires in retrospect, which may be susceptible to memory and affective biases (Nisbit & Ross, 1980; Olatunji, Leen-Feldner, Feldner, & Forsyth, 2007). Consistent with previous studies in adults and adolescents, the worry induction paradigm is an effective experimental approach to studying this risk factor in adolescents and allows the manipulation of worry related mood states to address causal pathways.

Despite the effectiveness of the worry induction procedure, active worry did not have an impact on adolescent's performance on the verbal or visuospatial working memory tasks. Contrary to expectations, worry did not impair working memory capacity as there were no differences on task performance between the worry and control groups. This is in contrast to previous studies in adolescents which demonstrate that high worry is associated with deficits in working memory capacity (Owens et al., 2012; Trezise & Reeve, 2014, 2016). One possible reason is that worry and anxiety mood states were not maintained whilst participants were completing the verbal and visuospatial working memory tasks. Mood states were measured after completion of the working memory tasks to check if the mood manipulation was sustained. The results showed that levels of worry and anxiety in the worry group decreased from post-induction to post-completion of the cognitive tasks. Whilst worry and anxiety in the control group did not significantly change from post-induction to post-completion of tasks. This suggests that worry and anxious mood states in the worry group may not have been maintained whilst they were completing the working memory tasks, which may have affected the results.

The decrease in negative affect indicates that perhaps adolescents became comfortable whilst completing the cognitive tasks and enjoyed completing the dynamic working memory tasks, which may be seen as a fun and challenging game. This is supported by analyses of the relaxed VAS measures from post-induction to post-completion of the task, which show a significant increase in relaxed mood states both in the worry and control groups.

Furthermore, both groups at post-completion of the tasks did not differ in terms of levels of worry, anxiety or relaxed mood states. Even though the worry topics participants had written down were placed next to them to increase proximity of worrisome thoughts during completion of the working memory tasks, and they were verbally instructed to continue thinking about their worrisome topics while they completed the task, this may not have been sufficient. It is difficult to assess how long worry or anxiety in the worry group was maintained during the completion of the working memory tasks and whether this accounted for the null findings. Previous studies in adults that involved a worry induction procedure followed by completion of cognitive tasks, included automatic reminders on the computer every minute during the task for participants to continue worrying or thinking about their worrisome topics (Hayes et al., 2008; Sari et al., 2016). Perhaps this may have been a more effective and salient technique to maintain the worry process after an induction period and evaluate the consequences of worry.

A second possible reason for the non-significant effects of worry on working memory capacity, is that the tasks in the present study used neutral as opposed to emotionally valenced stimuli. Whilst most studies have traditionally used complex span tasks with neutral stimuli as a reliable predictor of working memory capacity (Conway et al., 2005; Kane et al., 2004), some researchers have developed a complex span measure of emotional working memory capacity (eWMC) by introducing affective stimuli into the task paradigm (Schweizer & Dalgleish, 2011, 2016). The emotional working memory task involves participants recalling a list of neutral words, whilst simultaneously processing sentences describing trauma related thoughts relative to neutral sentences. In another version of the task, participants are presented with negatively aversive background images relative to emotionally neutral images. The studies found that community samples and clinical participants with PTSD showed reduced working memory capacity in the emotionally valenced contexts and performed worse compared to controls in their ability to recall neutral words, suggesting that emotional contexts take up cognitive capacity in working memory (Schweizer & Dalgleish, 2011, 2016).

These studies support the attentional control theory (ACT; Eysenck et al., 2007), which proposes that anxiety has a strong influence on working memory capacity in affectively charged situations. Perhaps emotional working memory tasks provide a more ecologically valid measure that reflects everyday mental health difficulties, such as performing routine cognitive operations whilst trying to ignore emotionally-laden thoughts, feelings, and images (Dalgleish, 2004). The results of the present study indicate that active worry in adolescents does not impair working memory capacity in tasks using neutral stimuli, however future studies should investigate whether worry in adolescents has an impact on cognitive capacity when the task involves emotionally-laden stimuli.

A third explanation that the results were not consistent with previous studies in adolescents that have found an association between worry and working memory capacity, is that prior studies did not include a worry induction procedure or measure the active worry process, rather used a self-report questionnaire to measure trait worry. Active worry is an effective approach to evaluating real-time features of worry on outcome measures, however it is susceptible to methodological shortcomings such as whether the worry is maintained after the induction period. In addition, the current sample were healthy adolescents and thus the nature of worry in community samples may be distinct to pathological worry in clinical samples. Moreover, the results showed that factors such as trait worry, trait anxiety, intolerance of uncertainty, attentional control, and emotional regulation do not influence participant’s performance on the working memory tasks in either the worry or control group. This indicates that working memory capacity in our adolescent sample did not depend on levels of trait worry, anxiety, intolerance of uncertainty or other executive control processes such as attentional control or emotion regulation.

The current study has a number of strengths and limitations. In contrast to the previous literature, worry in adolescents did not predict impaired working memory capacity. As discussed, the decrease in levels of state worry and anxiety in the worry group from post-induction to post-completion of the cognitive tasks, suggests that worry may not have been maintained during completion of the working memory tasks. This may have influenced the results and contributed to the absence of a difference between the worry and control groups on working memory capacity. The sample size was selected due to limited resources and time, however post-hoc power analysis revealed that this was an adequate sample size for detecting a medium effect. In addition, the sample size of the current study is larger than previous studies in adolescent and adult studies that have utilised a worry induction and have found significant results (Frala et al., 2014; Hayes et al., 2008; Stefanopoulou et al., 2014).

Furthermore, it is important to recognise that findings from the adult literature cannot be assumed to extend to youth (Cartwright-Hatton et al., 2011; Cicchetti & Rogosch, 2002). Studies in adults using a worry induction paradigm have shown that high worry predicts low working memory capacity (Hayes et al., 2008; Leigh & Hirsch, 2011; Rapee, 1993; Sari et al., 2016; Stefanopoulou et al., 2014), however these studies may not be replicable in child and adolescent populations due to differences in cognitive development and maturation. Adolescence represents a transition period of major cognitive, social emotional and developmental changes and further research investigating the nature and consequences of worry during this age is important to gain a better understanding of worry in youth.

To the best of our knowledge, this was the first study to investigate the impact of active worry on working memory capacity in adolescents. In line with a previous study in adolescents, the study demonstrated that worry inductions are effective experimental approaches to implement in adolescent populations to elicit negative worry affective states. In addition, this was the first study to examine verbal and visuospatial processes of working memory in adolescents and was designed to investigate how worry impairs components of working memory. Although, the current study found no differences between the worry and control groups on working memory capacity, further investigation into the verbal or visual nature of worry in adolescents is needed to understand the cognitive mechanisms to target for early interventions and strategies to improve current treatments. Whilst a large body of research in adults indicates that worry is a verbal process, there has been limited research on whether the experience of worry in adolescents is verbal or imagery related.

Future studies examining the verbal and visuospatial aspects of working memory that are affected during worry would provide greater insight into the worry process in youth. In addition, further research in adolescent worry employing working memory tasks with affective stimuli may capture emotional impairments better than complex span paradigms with neutral stimuli. The use of emotional working memory tasks may provide a more ecologically valid measure in the context of intrusive and worrisome thoughts in adolescents and have a more salient effect. Moreover, the use of worry induction procedures allow researchers to directly assess the consequences of worry in adolescents, which are more accurate real-time measures of worry compared to retrospective reports of worry. Future studies using this approach would enhance our current knowledge of worry and the impact on executive functions in adolescents.

Previous literature indicates that working memory is an important cognitive process involved in worry as it consumes the limited working memory capacity. However, there have been few experimental studies that have examined this in adolescents, with most studies correlational in design. Future research utilising an experimental approach and incorporating worry inductions would provide greater insight into the causal nature of worry. Furthermore, independent of adult research, future studies in adolescent populations should consider developmental processes when examining the trajectory of worry in youth, in order to illuminate our understanding of the cognitive mechanisms and causal pathways underlying worry in youth.

Chapter 7

7

Discussion

7.1. Overview

The research presented in this thesis investigated the role of cognitive biases and executive functions in adolescent worry. In particular, studies pertained to how attention bias, interpretation bias, memory bias, attentional control, and working memory operate in adolescent worry. Hirsch and Matthews' cognitive model of pathological worry (2012) provided a theoretical framework to guide the research in this thesis and each chapter examined whether aspects of the model were applicable to understanding adolescent worry. Overall, the theoretical and empirical chapters in this thesis addressed three key questions:

Research Question 1: Are cognitive biases associated with worry in adolescents, and what is the causal nature of these cognitive processes over time?

Research Question 2: Are executive functions associated with worry in adolescents, and how does high worry impact executive functions?

Research Question 3: Do executive functions moderate the relationship between cognitive biases and worry as proposed in Hirsch and Matthews' cognitive model of pathological worry (2012), and is this model applicable to understanding adolescent worry?

This final chapter summarises the main findings of each chapter and discusses the results in relation to the three research questions. The implications of these findings and recommendations for future research are then considered, in order to further improve understanding of the cognitive mechanisms underlying worry in adolescents.

7.2. Summary of results

Chapter Two reviewed the existing literature on cognitive biases and executive functions associated with worry in youth, and assessed the application of Hirsch and Matthews' cognitive model (2012) in understanding child and adolescent worry. The review found evidence in the child and adolescent literature for two of the building blocks proposed in Hirsch and Matthews' cognitive model of pathological worry. Studies showed that negative cognitive biases and deficits in executive functions were associated with high worry and GAD in children and adolescents. Consistent with the adult literature, youth with high worry or GAD tend to interpret ambiguity as more threatening compared to non-anxious youth, whilst evidence for a threat-related attention bias was mixed, and there was limited support for a memory bias towards threat in youth. In addition, studies showed that poor attentional control, reduced working memory capacity, and emotion dysregulation were associated with high worry or GAD in youth. However, the review found little support for the third component of Hirsch and Matthews' cognitive model (2012) in youth, suggesting that worry may not reflect the same verbal processes as those typically observed in adults. Thus, to facilitate a programme of research on important gaps in the literature, we proposed a cognitive model of child and adolescent worry to provide a framework for understanding the cognitive mechanisms underlying worry in youth. The findings of the systematic review provided a research framework to guide subsequent studies in this thesis.

Chapter Three addressed the first research question and investigated the association between cognitive biases and worry in adolescents. Specifically, whether attention bias, interpretation bias, and memory bias were related to levels of worry in adolescents. Data was drawn from time point 1 of the CogBias Longitudinal study and showed that high worry in adolescents, as measured with the Penn State Worry Questionnaire for Children (PSWQ-C), was associated with negative interpretations of social and non-social scenarios (AIBQ) and negative memory bias (SRET). Whilst, low worry in adolescents was related to positive interpretations of social and non-social scenarios, and positive memory bias. However, there was no evidence to support an association between worry and attention bias towards threat (Dot-probe task), which may be due to the low split half reliability of the Dot-probe task. Moreover, the combined cognitive bias hypothesis (Hirsch et al., 2006) was examined using PCA to create poly-bias scores, which resulted in four components termed a Negative Bias, Positive Bias, Attention Bias, and Attention Bias to Threat. Negative Bias, comprised of a combination of negative interpretation and negative memory biases, had the strongest association with high worry in adolescents. Whilst Positive Bias, consisted of positive interpretation and positive memory biases, were associated with low worry in adolescents. Attention Bias and Attention Bias to Threat was not associated with adolescent worry. Overall, the data suggests that interpretation and memory biases are closely interrelated cognitive processes associated with worry in early adolescents.

Chapter Four was designed to build on the findings of Chapter Three and examined the causal relationship between cognitive biases and worry in adolescents over time. A cross-lagged panel analysis was conducted to determine the stability and direction of causality between poly-bias scores and worry, using data collected at two time points of the CogBias Longitudinal study. One of the limitations identified in Chapter Two, was that most research on child and adolescent worry is correlational in design. Therefore, this longitudinal study examined the development of cognitive biases and worry over time to identify the causal pathways that may lead to adolescent worry. Following on from the previous chapter, a PCA was conducted on the cognitive bias variables at time point 2 and demonstrated that poly-bias scores behaved consistently across time, with Negative Bias, Positive Bias, and Attention Bias components emerging at both time points. The cross-lagged panel analysis showed that Negative Bias in early adolescence predicted high worry in mid-adolescence. Although, the reverse relationship was also significant, as high worry in early adolescence caused Negative Bias in mid-adolescence. There was no evidence to suggest that having a Positive Bias or Attention Bias in early adolescence predicted levels of worry in mid-adolescence. Furthermore, Negative Bias, Positive Bias, and worry remained stable cognitive processes from early to mid-adolescence, however having an Attention Bias was not consistent across time. Together, evidence in Chapters Three and Four indicate that interpretation and memory biases play an important role in adolescent worry, and are cognitive processes that may not operate in isolation, but rather influence each other during early to mid-adolescents.

Chapter Five investigated the role of executive functions in adolescent worry and addressed the second and third research questions presented in this thesis. Data was drawn from time point 2 of the CogBias Longitudinal study and assessed whether executive functions, in particular working memory (Corsi Block Tapping Task) or attentional control (Flanker Task), were associated with levels of worry in adolescents (PSWQ-C). Furthermore, the study examined whether these executive functions moderated the relationship between cognitive biases and worry, as proposed in Hirsch and Matthews' cognitive model of pathological worry (2012). Data showed that poor attentional control and low working memory capacity were not associated with high worry in adolescents. In addition, working memory and attentional control did not moderate the effect between cognitive biases and worry in adolescents. In contrast to the adult literature, the findings suggest that executive functions are not associated with the worry process in mid-adolescence and do not interact with cognitive biases.

Chapter Six further investigated the role of executive functions in adolescent worry and extended the findings of Chapter Five. This study addressed the second research question and a limitation identified in the youth literature that studies often rely on retrospective self-reports, questionnaires, vignettes, and interviews to assess the content, frequency, and cognitive correlates of worry. Therefore, an experimental study was designed to assess the direct effect of active worry on working memory capacity in adolescents, using a worry induction paradigm validated in adolescent (Frala et al., 2014) and adult samples (McLaughlin et al., 2007). Specifically, this chapter examined the direct influence of active worry on the visuospatial (Symmetry Span Task) and verbal (Digit Span Task) processes of working memory. Consistent with previous studies, the worry induction paradigm was effective in inducing greater levels of state worry and anxiety in a worry group compared to a control group, which provides support for the use of a worry induction paradigm in healthy adolescents. However, active worry did not impair performance on the verbal or visuospatial working memory tasks, as there were no differences on task performance between groups. Moreover, factors such as trait worry, trait anxiety, attentional control, intolerance of uncertainty, and emotional regulation did not influence performance on the working memory tasks. The data presented in Chapters Five and Six indicate that executive functions may not play an important role in the worry process during mid-adolescence, which perhaps reflects ongoing developmental and cognitive changes in the pre-frontal cortex of the adolescent brain.

In summary, the research presented in this thesis provides a deeper insight into the cognitive mechanisms underlying worry in adolescence, which are far less understood in comparison to advancements in the adult literature on worry and GAD. The strengths and limitations of the overall research in contributing to an understanding of worry in adolescence as well as considerations for future directions investigating the role of cognitive biases and executive functions in adolescent worry are discussed.

7.3. Strengths and limitations

The body of work presented in this thesis draws on Hirsch and Matthews' cognitive model of pathological worry (2012) as a theoretical framework for understanding the cognitive mechanisms in adolescent worry. A key strength of this thesis is the use of complementary research designs such as correlational, longitudinal, and experimental studies to investigate the gaps in the literature on adolescent worry that remain largely unexplored. In addition, novel ways of analysing the data through principle components analysis to create poly-bias scores and cross-lagged panel modelling are used to consider how cognitive processes operate during the early stages of adolescent worry. To the best of our knowledge, the theoretical and empirical chapters presented in this thesis are the first to examine the role of cognitive biases and executive functions in relation to adolescent worry. The findings of this thesis contributes to the growing body of research on the cognitive mechanisms underlying adolescent worry, which has important implications for identifying the cognitive processes to target for early interventions and treatments for worry in adolescents.

The systematic review in Chapter Two highlighted the lack of developmental models and the limited empirical evidence supporting the cognitive pathways that lead to worry in youth (Kertz & Woodruff-Borden, 2011; Vasey, 1993). The body of work presented in this thesis showed that interpretation bias and memory bias are important cognitive mechanisms associated with worry in adolescence, and importantly are interrelated cognitive biases that may work together during adolescence. This was supported by longitudinal data in Chapter Four, which demonstrated that poly-bias scores, a combination of interpretation and memory biases, remained stable from time point one (early adolescence) to time point two (mid-adolescence) and predicted levels of worry over time. The findings indicated that Negative Bias, Positive Bias, and the tendency to worry remained stable processes from early to mid-adolescence. Furthermore, Negative Bias in early adolescence predicted high worry in mid-adolescence, whilst high worry in early adolescence also predicted Negative Bias in mid-adolescence. These results provide preliminary evidence that contributes to a developmental understanding of how cognitive biases may operate and mature during adolescence, which are pathways that could be incorporated into future developmental models of worry to highlight the relationship between cognitive biases and adolescent worry.

Another strength of the research presented in this thesis is the exploration of the relationship between executive functions and adolescent worry. Contrary to the adult literature, executive functions such as working memory and attentional control were cognitive processes not associated with worry in our sample of adolescents. The findings in Chapter Five and Six indicate that executive functions may not play a role during adolescent worry, which is perhaps due to cognitive changes in the prefrontal cortex where executive processes are not yet fully developed. These studies provide further insight into the cognitive mechanisms underlying worry in adolescents and are important factors to consider when constructing a developmental model of worry in adolescence. Thus, the body of research provides preliminary evidence that cognitive processes associated with adult worry may differ in adolescence and adult models may not be fully applicable to younger generations given the different developmental stages attained (Cartwright-Hatton et al., 2011).

A number of limitations to the body of research presented in this thesis should be noted. Firstly, the non-significant findings pertaining to attention bias in the studies presented may be due to the poor split half reliability of the Dot-probe task in our sample of adolescents. Methodological issues such as the task parameters selected on the Dot-probe paradigm that include pictorial stimuli, adult faces, and shortened length of stimuli presentation may have influenced the reliability of the task and results. Therefore, attention bias findings need to be interpreted with caution and further replication, using other paradigms to assess attention bias such as the visual search task, the stroop task, emotional cueing task or eye tracking, is needed. Another limitation to the research presented in this thesis is that the studies empirically examined two of the cognitive elements of Hirsch and Matthews' model of pathological worry (2012) in adolescence, however the third component of the model relating to the verbal nature of worry was not assessed. Due to time and resource restrictions within the scope of research, the present study did not investigate the nature of worry in adolescence and whether this process reflects verbal worry or imagery based worry. Previous studies highlighted in the systematic review, suggest that worry in youth may not reflect the same verbal worry processes as those observed in adults, which perhaps reflects more advanced stages of cognitive development. Experimental studies and within subject designs comparing verbal worry versus imagery based worry would be an interesting line of research for future studies and contribute to a developmental perspective on the nature of worry in youth.

A further limitation to the thesis is that the studies use chronological age as a marker for development and arbitrary age ranges to determine early to mid-adolescence, rather than measures that assess levels of cognitive development or pubertal stage, which may vary within adolescents of the same age. The inclusion of other assessments to consider adolescent cognitive development, such as conservation and logical reasoning tasks (Frala et al., 2014) or questions regarding puberty (Caes et al., 2016) may be a more robust way of measuring the varying levels of development within adolescence that may influence how the nature of worry changes across time. It would be useful for future developmental models on worry to incorporate and consider how factors such as puberty, cognitive development, and the verbal or visual nature of worry influences worry across time. Future longitudinal research investigating the role of cognitive elements in the trajectory of worry from early, mid, to late adolescence would provide further insights into the cognitive pathways to target for early interventions and treatments. Future directions in relation to the findings of the thesis are now discussed.

7.4. Future directions for studies on cognitive biases and adolescent worry

The data reported in Chapters Three and Four addressed the first research question regarding the relationship between adolescent worry and cognitive biases, specifically, attention bias, interpretation bias, and memory bias. Taken together, the findings indicate that interpretation bias and memory bias play an important role in the process of worry in adolescence. For instance, adolescents with high worry in our sample tended to interpret ambiguous scenarios as more threatening, as well as endorsed and recalled more negative self-referent information. Moreover, a combination of negative interpretation and negative memory biases, which we termed a Negative Bias poly-bias score, were significant causal pathways for worry from early to mid-adolescence. These findings provide support for the combined cognitive bias hypothesis in adolescents and suggests that interpretation and memory biases are interrelated cognitive processes that work together and influence the development of worry. However, attention bias was not associated with adolescent worry, and importantly, did not correlate with the interpretation or memory bias variables in the PCA conducted in Chapters Three and Four.

There are several possible reasons as to why attention bias towards threat was not associated with worry in our sample of adolescents at time point 1 and time point 2, that warrant further discussion. Firstly, the non-significant findings may be due to the low split half reliability of the Dot-probe task in our sample of adolescents, with the Dot-probe task generally yielding inconsistent results in anxious youth (Dudeney et al., 2015). Methodological differences in studies using the Dot-probe task with variations in task parameters, linguistic or pictorial stimuli, length of presentation time, calculation of bias indices, study designs, and comparison groups has generally contributed to the mixed findings in the literature of an attention bias towards threat in youth with GAD (Abend et al., 2017; Dalgleish et al., 2003; Roy et al., 2008; Taghavi et al., 1999; Waters et al., 2008, 2014). Secondly, the group testing conditions for the data collection in Chapters Three and Four may have further compromised the validity of the Dot-probe task and interfered with adolescent's concentration levels to capture attention during the task. Analysis of the split half reliability of the Dot-probe task in this thesis showed low reliability (Parsons, 2017), which indicates that the task was not a stable measure of attention bias in our sample. Thirdly, the non-significant findings associated with the Dot-probe task may be due to age-related effects, with evidence in a recent meta-analysis suggesting that differences in attentional processing of threat was strongly moderated by age (Dudeney et al., 2015).

Therefore, further replication and examination of the reliability of the Dot-probe task in youth is needed to determine whether the task is a robust measure for capturing attentional processing. Importantly, studies that find non-significant effects should be published in the literature to help guide future research and inform task selection. Perhaps the use of other paradigms such as eye tracking, the visual search task, emotional cueing task, or stroop task may be more appropriate measures to use in future research of attention bias in adolescents. In addition, standardisation of the Dot-probe task is warranted to find meaningful effects and improve comparability amongst studies in attention bias research. Finally, most studies in the youth literature on worry or GAD often combine child and adolescent age groups. However, future research examining attention biases in adolescent populations would help disentangle age-related differences in attentional processes and provide greater insight into attention biases, which emerge at various stages of development.

The data presented in Chapters Three and Four used a novel approach to investigating the combined cognitive bias hypothesis, by creating poly-bias scores to examine the interrelationships amongst cognitive biases (Orchard & Reynolds, 2017, unpublished manuscript). The findings offer preliminary support for the combined cognitive bias hypothesis in adolescents (Klein et al., 2017, Higa et al., 2008; Orchards & Reynolds, 2018; Vassilopoulos, 2012) and provides a deeper insight into how attention, interpretation, and memory biases influence each other and contribute to varying levels of adolescent worry. The findings indicate that adolescent worry may be more related to the interpretation of ambiguity and memory recall, which are cognitive processes that work more closely together, rather than the initial capture of attention towards threatening or negative information.

Broadly, this is consistent with cognitive models of anxiety in youth, which suggest that interpretation and memory biases occur at the later stages of information-processing, after initial attention is captured and encoded in the cognitive system (Crick & Dodge, 1994; Daleiden & Vasey, 1997; Muris & Field, 2008). However, further replication and validation of this method is warranted and future research should aim to investigate the interplay amongst cognitive biases, rather than examining biases in isolation. In particular, cognitive biases in adolescence may work more closely together at this important developmental stage and future research examining the interrelationships amongst these cognitive biases would provide greater insights into the risk and protective mechanisms underlying worry in youth. Further studies should also assess whether the poly-bias approach is a better predictor of worry in adolescence compared to studying biases in isolations, which has important implications for informing research and tailoring early interventions. Some studies in adults have examined the combined cognitive bias hypothesis using an integrated task that measures the direct influence of attention bias, interpretation bias, and memory biases simultaneously and how these cognitive processes interact in the manifestation of anxiety (Everaert et al., 2013; 2014; Koster et al., 2010). Future studies in adolescents employing similar tasks would help to identify the cognitive biases that contribute to the worry process and how these processes interact.

7.5. Future directions for studies on executive functions and adolescent worry

The research presented in Chapters Five and Six addressed the second and third research questions, and found that executive functions were not associated with worry in adolescents. The studies presented demonstrated that the executive functions of working memory and attentional control were not related to high worry in two independent samples of mid-adolescents. In addition, Chapter Five showed that executive functions did not moderate the relationship between cognitive biases and worry in adolescents. Whilst evidence presented in this thesis supports the role of cognitive biases in adolescent worry, the data does not support the role of executive functions in adolescent worry as outlined in Hirsch and Matthews' cognitive model. As demonstrated in Chapters Three and Four, perhaps cognitive biases are more potent cognitive processes involved in adolescent worry and are 'bottom-up' processes that play a greater role, in comparison to 'top-down' executive functions. Overall, the empirical data presented in this thesis indicates that Hirsch and Matthews' model of pathological worry (2012) may not be fully applicable to understanding worry in adolescence, as evidence did not support the role of executive functions in adolescent worry.

Several possible reasons such as the complex nature of measuring executive functions, the reliability of executive function tasks in youth, and developmental considerations of cognitive changes throughout adolescence, may contribute to the lack of significant findings in Chapters Five and Six. One issue debated amongst researchers is whether executive functions show a general pattern of shared but distinct functions, referred to as unity and diversity (Diamond, 2013; Friedman & Miyake, 2017). It has been argued that due to the complex organisation of these cognitive abilities, executive function tasks may be tapping into shared components of cognitive processing, making it challenging to measure individual executive functions. Moreover, studies in youth have shown low inter-correlations and reliability amongst executive functions tasks that measure the same construct (Burgess, 1997; Friedman & Miyake, 2017; Shallice & Burgess, 1996; Stuss & Alexander, 2000). Perhaps the working memory and attentional control tasks assessed in Chapters Five and Six tap into several aspects of cognitive abilities in adolescence, which make it difficult to disentangle effects.

Considering that there is limited research that investigates the role of executive functions in adolescent worry, future studies should aim to validate and replicate existing studies in order to inform better task choice and improve methodology. For instance, further research could utilise multiple measures of the same construct to target the underlying executive function. This would enable researchers to better understand whether executive function tasks measuring the same construct are correlated in adolescence, and may provide a purer measure of the cognitive ability of interest. Furthermore, following on from recent experimental studies in the adult literature on worry and GAD, Chapters Five and Six focused on the role of working memory and attentional control in adolescent worry (Hayes et al., 2008; Fox et al., 2015; Leigh & Hirsch, 2011; Rapee, 1993; Sari et al., 2016; Stefanopoulou et al., 2014). However, other aspects of executive control processes may also have an impact on the process of worry in adolescents and future studies could examine the interrelationships amongst inhibition, working memory, and cognitive flexibility and how these processes operate and interact during adolescent worry (Miyake et al., 2000).

Moreover, as suggested in Chapter Four, the use of affective stimuli in working memory tasks may provide a more ecologically valid measure of the intrusive nature of worrisome thoughts in adolescents. Evidence in adult studies have shown that working memory tasks using emotional content, such as trauma related thoughts or negatively aversive images, reduced working memory capacity in participants with PTSD and community samples (Schweizer & Dalgleish, 2011, 2016). Perhaps adapting the executive function tasks in Chapters Five and Six to include affective stimuli may have a more salient effect on assessing the role of ‘top-down’ processes in adolescent worry. For instance, using emotionally-laden words or images, especially negative or threat-related stimuli in the Flanker Task, Corsi-Block Tapping Task, Digit Span Task, and Symmetry Span would be an interesting direction for future research. The use of affective stimuli in tasks would be consistent with the cognitive bias measures presented in this thesis, which yielded significant results. The findings in Chapters Five and Six indicate that worry does not have an impact on executive functions, in particular in tasks using neutral stimuli. However, it is unknown whether worry in adolescents only affects executive functions when a task includes affectively valenced stimuli. Future studies could replicate the findings of Chapter Five and Six using executive function tasks with neutral stimuli, whilst running in parallel the same set of studies using executive function tasks with negative affective stimuli, to compare adolescent’s performance. In particular, the use of negative affective stimuli in cognitive tasks may better reflect everyday difficulties experienced during worry, such as performing routine cognitive operations whilst simultaneously ignoring emotionally-laden thoughts, feelings, and images (Dalgleish, 2004).

In addition to issues relating to the reliability of executive function tasks, developmental changes in the prefrontal cortex and neural networks in the adolescent brain may explain the lack of significant findings in Chapters Five and Six (Fuhrmann et al., 2015;

Steinberg, 2014). Perhaps in mid-adolescence, ‘top-down’ executive processes work more closely together with ‘bottom-up’ cognitive biases, which may only begin to separate and become more distinct in young adulthood. Thus, the role of executive functions in relation to habitual thought patterns of worry may emerge at later stages of cognitive development in older adolescents or young adulthood as the brain continues to mature. A direction for future studies would be to examine the developmental trajectory of executive functions throughout early, mid, to late adolescence and early adulthood, and assess how changes in these cognitive processes influence worry over time. With few studies in the literature investigating the role of executive functions in adolescent worry, these recommendations provide a clear direction for future research.

7.6. General future directions

In addition to the recommendations for future research on cognitive biases and executive functions discussed above, there are a number of questions that remain to be addressed in regards to worry in adolescents.

7.6.1. A developmental approach

An important direction for future research on adolescent worry is to investigate the cognitive mechanisms of worry within a developmental framework, taking into consideration developmental changes throughout adolescence, which may influence the nature and experience of worry in youth. Adolescence is a period that entails major cognitive, social, and physiological changes that impact on the development of worry (Copeland et al., 2014). However, how these developmental factors contribute to the trajectory of pathological worry in adolescents are poorly understood. There are few developmental models and limited empirical evidence on the cognitive pathways that lead to pathological worry in youth (Kertz

& Woodruff-Borden, 2011; Vasey, 1993), which often results in adult conceptualisations of worry being applied to children and adolescents (Cartwright-Hatton et al., 2011). Although informative, these adult models may not be fully appropriate to understanding the nature of worry in younger populations. For instance, the empirical data presented in this thesis demonstrates that only certain aspects of Hirsch and Matthews' cognitive model of pathological worry (2012), such as the role of cognitive biases, are applicable to understanding the process of worry in youth.

Furthermore, incorporating a developmental perspective to Hirsch and Matthews' cognitive model of pathological worry (2012) that emphasises on the importance of cognitive, emotional, social, and age-related changes that influence the aetiology of worry in youth may be a useful framework for future research. Important questions remain such as how these cognitive processes outlined in the model, including cognitive biases, executive functions, and the verbal nature of worry, develop over time and influence worry in adolescence. Whilst the studies presented in this thesis investigated the role of cognitive biases and executive functions during adolescent worry, it would be interesting to assess how these processes evolve in late adolescence and early adulthood when maladaptive thoughts and behaviours may become more habitual. In addition, examining how these cognitive mechanisms begin to evolve in earlier stages of middle childhood when worry starts to become more concrete (Vasey, 1993; Vasey et al., 1994) may also provide further insights into the cognitive pathways to pathological worry. There are limited studies that have examined how cognitive biases and executive functions develop throughout the lifespan, in particular in relation to worry and in light of neurocognitive plasticity in the brain. Importantly, future research employing longitudinal studies and experimental designs would allow researchers to examine the causal nature of these cognitive processes and consider how key developmental transitions may affect worry in adolescence.

7.6.2. The verbal nature of worry

Furthermore, future research should investigate the nature of worry in adolescents and how developmental factors influence the verbal or imagery based processing of worry in youth. As reviewed in Chapter Two, there is limited research on how children and adolescents experience worry (Carr & Szabó, 2015; Fialko et al., 2012; Gosselin et al., 2007; Laugesen, et al., 2003; Szabó, 2007), which may not reflect the same verbal processes as those observed in adult worry or GAD. Moreover, empirical data in Chapter Five demonstrates that active worry does not impair visuospatial and verbal processes of working memory in adolescents. Thus, it is unclear whether adolescents worry in verbal or imagery form or at what age the verbal nature of worry develops. Future research investigating the nature of worry in adolescents and comparing whether verbal worry or visual worry is more intrusive in youth, would provide greater insight into the cognitive mechanisms to target for early interventions and strategies to improve current treatments.

7.6.3. Measuring worry in youth

Assessing worry in youth can be challenging given developmental issues in the changing nature of worry, differences in the conceptual understanding of worry in children and adolescents, and varying instruments measuring the fine line between pathological and non-pathological worry (Cartwright-Hatton, 2006). There are few valid self-report measures that specifically assess general worry in child and adolescent populations including the Penn State Worry Questionnaire for Children (Chorpita et al., 1997), Things I Worry About Scale (Miller & Gallagher, 1996), and The Worry Scale (Perrin & Last, 1997). Whilst the Penn State Worry Questionnaire for Children has become one of the most commonly used and reliable assessment tools for measuring worry in clinical and non-clinical populations in youth, there are some constraints when using self-report measures to assess worry in youth.

For instance, worry questionnaires in youth are often drawn from adult conceptualisations of worry and anxiety (Henker et al., 1995). Thus, the nature of worry in children and adolescents and whether this differs from adults, needs to be thoroughly examined and reflected in assessment tools that are appropriate for measurement in youth (Cartwright-Hatton, 2006).

Furthermore, the majority of research on child and adolescent worry has relied on retrospective self-reports, questionnaires, vignettes, and interviews to assess worry. In contrast, a large body of research in adults have utilised worry induction paradigms to examine the consequences of active worry, which have contributed to a greater understanding of the worry processes (Behar et al., 2005; Borkovec et al., 1998; McLaughlin et al., 2007; Meeten & Davey, 2011). Data presented in Chapter Six demonstrated that worry inductions are effective experimental approaches to implement in adolescent populations to elicit negative worry affective states. Only one study in adolescents has utilised a worry induction paradigm (Frala et al., 2014), which highlights that the experimental literature on worry in youth has lagged behind. Future studies that incorporate worry induction paradigms to measure active worry could be an important direction to advance understanding and research in this field. Investigating the direct impact of worry on cognitive functions in adolescents using real-time measures, may provide a more accurate assessment of the worry process and address some limitations of using retrospective self-report questionnaires in youth.

7.6.4. The trajectory of normal worry

Finally, a consideration for future research in adolescent worry is investigating the worry process in healthy, non-clinical adolescent populations and how this develops over time. Research presented in this thesis constitutes data from healthy community samples of adolescents, which provides insight into how worry develops in the early stages before it manifests into pathological worry. A deeper understanding of how negative intrusive thoughts in adolescents can sometimes develop into the pathological worry observed in GAD and other anxiety disorders, has the potential to prevent long-term negative outcomes. The studies presented in this thesis provide preliminary support for the cognitive mechanisms that may be beneficial to target in early interventions and improve current treatments for adolescent worry. For instance, negative interpretation bias and negative memory bias, or a combination of these cognitive processes, have shown to play an important role in adolescent worry and may be potential cognitive targets in the pathways to pathological worry. Perhaps school programmes implementing behavioural strategies that target these processes in healthy adolescents and integrating these into school curriculums, could have potentially long-term benefits of teaching adolescents how to manage and transform maladaptive cognitive biases before they develop into habitual thought patterns.

In addition, future research investigating the efficacy of CBM interventions in anxious youth is needed. Further refinement and improvement of CBM procedures and methodologies in adolescents, would provide a better understanding of whether CBM is a viable intervention in youth (Krebs et al., 2018). Whilst the field of CBM is still in its early stages, the potential value of CBM as a training technique to modify maladaptive cognitive biases is promising, and may be an effective addition to improving current treatments and interventions for worry or anxiety in youth. However, further work is needed to understand the cognitive mechanisms underlying worry in youth to identify potential cognitive targets.

Furthermore, in the clinical domain, disorder-specific treatments for GAD in children and adolescents are lacking, with few studies investigating the efficacy of treatments that target the specific cognitive mechanisms involved in the aetiology of pathological worry in youth (Holmes et al., 2014; Leger et al., 2003; Payne et al., 2011). Researchers suggest that current treatments for GAD in youth do not address the underlying cognitive mechanisms that have been empirically associated with pathological worry (Holmes et al., 2014). Further studies examining the cognitive mechanisms underlying worry in adolescents would help to identify potential cognitive targets to improve current treatments and drive future innovations.

7.7. Conclusion

Worry is common in adolescence and has a profound impact on daily functioning and mental health outcomes. Given that pathological worry is an important cognitive pathway in the development of anxiety disorders and long term negative consequences, research investigating the causal mechanisms underlying worry is imperative. The theoretical and empirical body of research presented in this thesis extends the existing knowledge on the cognitive mechanisms underlying worry in adolescence. Findings provide preliminary evidence for the role of cognitive biases in adolescent worry and identifies potential cognitive targets for early interventions and treatments for worry. Whilst the body of literature on adolescent worry is growing, there are still areas that remain largely unexplored. Importantly, there is a need for further longitudinal and experimental studies to investigate how cognitive processes associated with worry interact and change over time. Adolescence represents a vulnerable period that offers a unique opportunity to turn the trajectory and developmental course of worry around in its early stages. A deeper understanding of how cognitive mechanisms operate during adolescent worry is an important line of research and essential for building emotionally resilient adolescents well into adulthood.

8

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Appendices

A

Database Search for the Systematic Review in Chapter Two

Search Terms

Worry related subject headings included: *Generalized Anxiety Disorder* and text words included: *worry, generalized anxiety disorder, or GAD.*

These terms were paired with key terms related to *Information-processing biases* and subject headings included: *Cognitive Bias, Cognitive Processes, Information Processing Model, Attention Bias*, and *Interpretive Bias.* Text words included: *cog* bias, cog* process*, cog* process* bias*, cog* factor*, information process* bias, emotion process* bias, cog* model, attention* bias, interpret* bias* and *memory bias.*

These terms were also paired with key terms related to *Executive functions* and subject headings included: *Executive Function, Cognitive Control, Set Shifting, Emotion regulation* and *Emotional Control*. Text words included: *atten* control, executive function, cog* control, inhibit* control, executive control, emotion* control, emotion*reactivity, working memory, cog* flexibility, inhibition, set shifting* and *updating.*

These terms were also paired with key terms related to *Verbal processing of worry* and subject headings included: *Intrusive thought.* Text words included: *verbal, intrusive thought* and *neg* intrusion*.*

All terms were paired with the population of interest related terms: *adolescen*, child** and *youth.*

Quality Checklist of Studies in the Systematic Review

Table A.1

Summary of Quality Ratings of Studies in the Systematic Review

	Sections						
Studies	A	B	C	D	E	F	**Global rating**
Abend et al. (2017)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Affrunti & Woodruff-Borden (2017)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Bogels et al. (2003)	Strong	Moderate	Moderate	Moderate	Strong	N/A	**Strong**
Burgers & Drabick (2016)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Carr & Szabó (2015)	Strong	Moderate	Moderate	Moderate	Strong	N/A	**Strong**
Dalgleish et al. (2003)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Eschenbeck et al. (2004)	Strong	Moderate	Moderate	Moderate	Strong	N/A	**Strong**
Fialko et al. (2012)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Frala et al. (2014)	Strong	Strong	Strong	Strong	Strong	N/A	**Strong**
Geronimi et al. (2016)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Gosselin et al. (2007)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Gramszlo & Woodruff-Borden (2015)	Strong	Moderate	Weak	Moderate	Strong	N/A	**Moderate**
Gramszlo et al. (2017)	Strong	Moderate	Weak	Moderate	Strong	N/A	**Moderate**
Laugesen et al. (2003)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Matthews et al. (2014)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Owens et al. (2012)	Strong	Moderate	Weak	Moderate	Strong	N/A	**Moderate**
Roy et al. (2008)	Strong	Strong	Strong	Strong	Strong	Strong	**Strong**
Sportel et al. (2011)	Strong	Moderate	Moderate	Moderate	Strong	N/A	**Strong**
Suarez & Bell-Dolan (2001)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Suarez-Morales & Bell (2006)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Suveg et al. (2009)	Strong	Strong	Strong	Moderate	Strong	Weak	**Moderate**
Szabó (2007)	Strong	Moderate	Moderate	Strong	Strong	N/A	**Strong**
Taghavi et al. (1999)	Strong	Strong	Strong	Moderate	Strong	N/A	**Strong**
Taghavi et al. (2000)	Strong	Strong	Strong	Moderate	Strong	N/A	**Strong**
Taghavi et al. (2003)	Strong	Strong	Strong	Moderate	Strong	N/A	**Strong**
Trezise & Reeve (2014)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Trezise & Reeve (2016)	Strong	Moderate	Strong	Moderate	Strong	N/A	**Strong**
Verstraeten et al. (2011)	Strong	Moderate	Moderate	Moderate	Strong	N/A	**Strong**
Waters et al. (2008)	Strong	Strong	Strong	Moderate	Strong	N/A	**Strong**
Waters et al. (2014)	Strong	Strong	Strong	Moderate	Strong	N/A	**Strong**

Note. Quality assessment tool (Effective Public Health Practice Project, 1998); 3-point rating scale = Strong/Moderate/Weak

[a] **A** = Selection Bias; **B** = Study Design; **C** = Confounders; **D** = Blinding; **E** = Data Collection Methods; **F** = Withdrawals/ Drop-outs at follow-up

B

Penn State Worry Questionnaire – Child version

The *Penn State Worry Questionnaire – Child version (PSWQ-C)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Chorpita, B. F., Tracey, S. A., Brown, T. A., Collica, T. J., & Barlow, D. H. (1997). Assessment of worry in children and adolescents: An adaptation of the penn state worry questionnaire. *Behaviour Research and Therapy, 35*(6), 569-581.

C

Trial Sequence for the Dot-probe Task

The *Figures C.1 and C.2* originally presented here cannot be made freely available via ORA because of copyright. The images were sourced at:

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*, 15-20.

Roy, S., Roy, C., Éthier-Majcher, C., Fortin, I., Belin, P., & Gosselin, F. (2007). STOIC: A database of dynamic and static faces expressing highly recognizable emotions.

D

Ambiguous Scenarios in the AIBQ

The *Adolescents Interpretation and Beliefs Questionnaire (AIBQ) – Ambiguous Social Scenarios* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Miers, A. C., Blöte, A. W., Bögels, A. M., & Westenberg, M. (2008). Interpretation bias and social anxiety in adolescents. *Journal of Anxiety Disorders, 22*(8), 1462-1471.

The *Adolescents Interpretation and Beliefs Questionnaire (AIBQ) – Ambiguous Non-Social Scenarios* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Miers, A. C., Blöte, A. W., Bögels, A. M., & Westenberg, M. (2008). Interpretation bias and social anxiety in adolescents. *Journal of Anxiety Disorders, 22*(8), 1462-1471.

E

Lists of Words in the SRET

The *word list* originally presented here cannot be made freely available via ORA because of copyright. The words were sourced at:

Hammen, C., & Zupan, B. A. (1984). Self-schemas, depression, and the processing of personal information in children. *Journal of Experimental Child Psychology, 37*(3), 598-608.

F

Principle Components Analysis (PCA) Excluding the Attention Bias Variables

Factor loadings for Time point 1 of the CogBias Longitudinal study, excluding the attention bias variables (angry bias, happy bias, and pain bias) from the Dot-probe task.

Table F.1

Factor Loadings for Principle Components Analysis excluding Attention Bias at Time Point 1

Item	Positive Bias	Negative Bias
Positive Interpretations_social	-.85	
Positive Interpretations_non-social	-.72	
Positive Memory Bias	-.53	
Negative Interpretations_non-social		.88
Negative Interpretations_social		.80
Negative Memory Bias	.45	.44

Note. Principle Components Analysis using Oblimin rotation; Factor loadings < .30 are omtted

Factor loadings for Time point 2 of the CogBias Longitudinal study, excluding the attention bias variables (angry bias, happy bias, and pain bias) from the Dot-probe task.

Table F.2

Factor Loadings for Principle Components Analysis excluding Attention Bias at Time Point 2

Item	Negative Bias	Positive Bias
Negative Interpretations_social	.88	
Negative Interpretations_non-social	.87	
Negative Memory Bias	.62	
Positive Interpretations_social		-.83
Positive Interpretations_non-social		-.81
Positive Memory Bias		-.60

Note. Principle Components Analysis using Oblimin rotation; Factor loadings < .30 are omtted

G

Corsi Block Tapping Task

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2000). The corsi block-tapping task: Standardization and normative data. *Applied Neuropsychology*, *7*(4), 252-258.

H

Flanker Task

The *Figures H.1 and H.2* originally presented here cannot be made freely available via ORA because of copyright. The images were sourced at:

Eriksen, C. W. (1995). The flanker task and response competition: A useful tool for investigating a variety of cognitive problems. *Visual Cognition*, *2*(2-3), 101-118.

I

Revised Child Anxiety and Depression Scale – Short Version

The *Revised Child Anxiety and Depression Scale – Short version (RCADS-S)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Ebesutani, C., Reise, S. P., Chorpita, B. F., Ale, C., Regan, J., Young, J., Higa-McMillan, C., & Weisz, J. R. (2012). The revised child anxiety and depression scale-short version: Scale reduction via exploratory bifactor modeling of the broad anxiety factor. *Psychological Assessment, 24*(4), 833-845.

J

Emotion Regulation Questionnaire – Child and Adolescent version

The *Emotion Regulation Questionnaire – Child and Adolescent version (ERQ-CA)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Gullone, E., & Taffe, J. (2012). The emotion regulation questionnaire for children and adolescents (ERQ-CA): A psychometric evaluation. *Psychological Assessment*, *24*(2), 409-417.

K

Attentional Control Scale – Child version

The *Attentional Control Scale – Child version (ACS-C)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, *111*, 225-236.

L

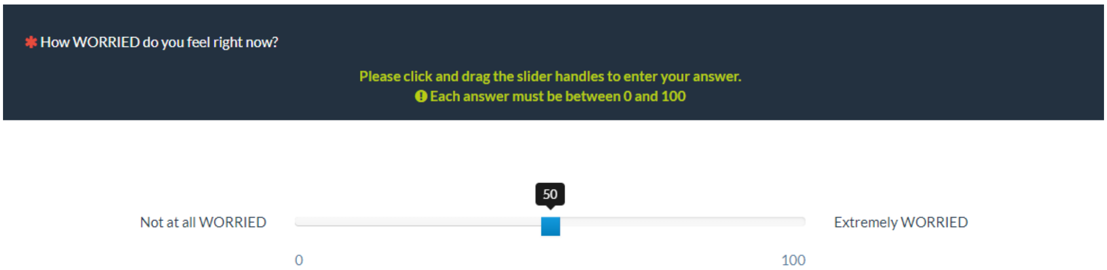
Intolerance of Uncertainty Scale – Child version

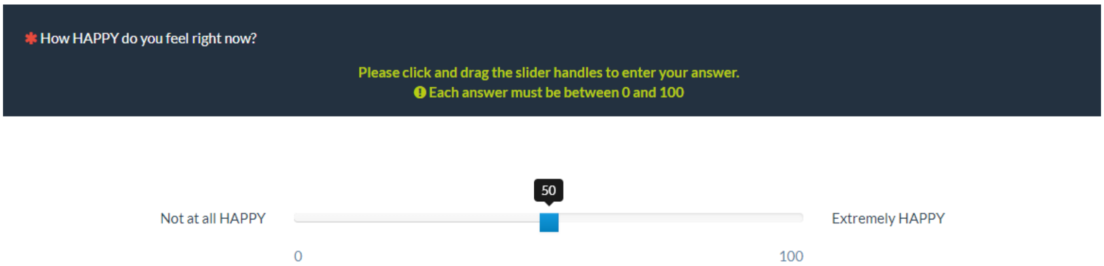
The *Intolerance of Uncertainty Scale – Child version (IUS-C)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

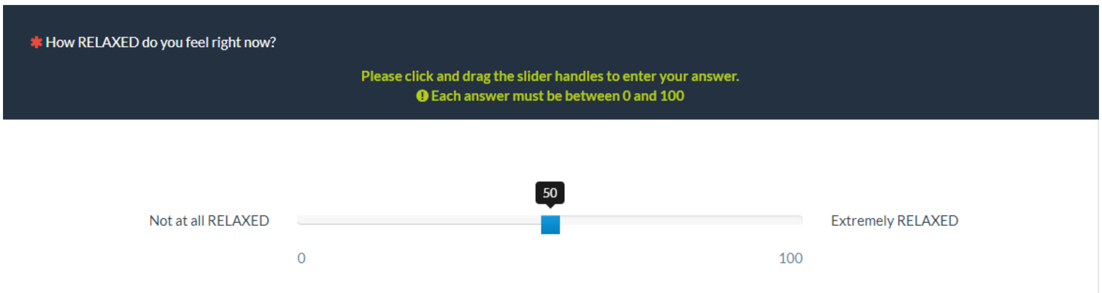
Comer, J. S., Roy, A. K., Furr, J. M., Gotimer, K., Beidas, R. S., Dugas, M. J., & Kendall, P. C. (2009). The intolerance of uncertainty scale for children: A psychometric evaluation. *Psychological Assessment, 21*(3), 402-411.

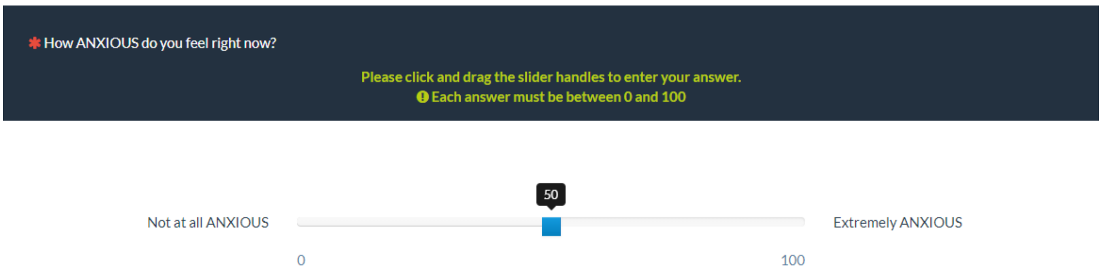
M

Visual Analogue Scales in Chapter Six









N

The State-Trait Anxiety Inventory

The *State-Trait Anxiety Inventory (STAI-S)* originally presented here cannot be made freely available via ORA because of copyright. The questionnaire was sourced at:

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.

O

Digit Span Task

The *Figure O.1* originally presented here cannot be made freely available via ORA because of copyright. The image was sourced at:

Woods, D. L., Kishiyama, M. M., Yund, E. W., Herron, T. J., Edwards, B., Poliva, O., Hink, R. F., & Reed, B. (2011) Improving digit span assessment of short-term verbal memory. *Journal of Clinical and Experimental Neuropsychology*, *33*(1), 101-111.

P

Symmetry Span Task

The *Figure P.1* originally presented here cannot be made freely available via ORA because of copyright. The image was sourced at:

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working memory capacity: A latent variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology: General*, *133*, 189-217.